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MMS 92-0029

FINAL REPORT

DISTRIBUTION, ABUNDANCE AND BEHAVIOR OF ENDANGERED WHALES IN THE ALASKAN CHUKCHI AND WESTERN BEAUFORT SEAS, 1991: WITH A REVIEW 1982-91

SEPTEMBER 1992

Prepared for:

Minerals Management Service
Alaska OCS Region
U.S. Department of Interior
Anchorage, Alaska 99508-4302

Prepared by:

Sue E. Moore and Janet T. Clarke
SAIC, Maritime Services Division
2845-D Nimitz Blvd.
San Diego, California 92106

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This report summarizes the 1991 investigations of the distribution, abundance, ation timing and route, behavior, and habitat -relationships of, endangered whales in the kan Chukchi and western Beaufort seas (hereafter, study area); 1991 was" the third year of a e year (1989-91) study. Data were collected during transect and search surveys flown in a ially modif ied Grumman Goose (model G21G) aircraft over the study area f rom 20 September ugh 7 November. The Bering Sea stock of bowhead whales (Balaena mysticetus) was the cipal species studied. Gray whales (Eschrichtius robustus) were also studied, with inciden sightings of all other marine mammals routinely recorded. Data collected during the 1991 y were subsequently integrated with the results of surveys conducted from 1982-1990.

In 1991, there were 27 sightings of 32 bowhead whales and 20 sightings of 26 gray es in the study area from 20 September through October. Over ten survey seasons (1982-91) , e were 267 sightings of 552 bowhead whales and 167 sightings of 424 gray whales. Bowheads seen from 18 September (1983) to 31 October (1991) , with peaks in sighting rates in early id-October. Bowheads migrate westerly (272°T) close to shore in the western Beaufort Sea, most disperse southwest (248°T) across the Chukchi Sea, with a few sightings north of 72% tude suggesting that some whales take a northerly route across the Chukchi Sea. Most gray es were feeding (84%), either along the crest or near relatively shallow shoals in the h and south-central Chukchi Sea. Distribution of random bowhead and belukha sightings cate migratory axes in the northeastern Chukchi Sea may be influenced by current patterns.

ocument Analysis a. Descriptors

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owhead whale	Alaska	OCS Playing Area	Abundance
alaena mysticetus	Endangered whales	Belukha	Behavior
ray whale	Beaufort Sea	Pinniped	
schrichtius robustus	Chukchi Sea	Distribution	

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San Diego, California 92106

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DISCLAIMER

This report has been reviewed by the Alaska Outer Continental Shelf Region, Minerals Management Service, U.S. Department of the Interior and approved for publication. The opinions, findings, conclusions or recommendations expressed in this report are those of the authors, and do not necessarily reflect the views of the Minerals Management Service. Mention of trade names or commercial products does not constitute endorsement or recommendation for use. This report has not been edited for conformity with Minerals Management Service editorial standards.

PROJECT ORGANIZATION AND ACKNOWLEDGEMENTS

This report is an account of a field study of endangered whales in the Alaskan Chukchi and western Beaufort seas conducted by the Maritime Services Division of Science Applications International Corporation (hereafter, SAIC) for the U.S. Minerals Management Service (MMS), Alaska Outer Continental Shelf (OCS) Region. The report describes results from field work conducted from 20 September through 7 November 1991, the final season of a three-year study. These results are subsequently integrated 'with those from surveys conducted from 1982-90 to provide a ten-year review for endangered whales and other marine mammals in the study area.

At the MMS, Anchorage, AK, we appreciate the advice and support of J. Imm, C. Cowles and S. Treaty. For logistic support we are especially grateful to pilots G. Candee, J. Gustafson, D. Henley, D. Moore and B. Points, and the administrative and maintenance staffs at the Office of Aircraft Services (OAS), Anchorage, AK, for providing the Grumman Goose (N780) survey aircraft. We also thank the Bensons and T. Frier at the Barrow Airport Inn, Barrow, AK for assistance during field operations. M. Johnson and M. Newcomer of SAIC were exceptional field observers during each field season 1989-91 and directly participated in the acquisition of all data upon which the results of this study rest, M. Johnson also provided timely data analysis, figure preparation and repott editing. D. McElroy provided gray whale sighting information collected during ARCO flights. R. Smith (SAIC) provided exceptional computer support, and J. La Nell and J. Candler (SAIC) assisted in travel logistics and report preparation. J. Groves of the University of Alaska-Fairbanks Geophysical Institute provided graphic analyses of 1991 ice concentrations and gamely tracked down historical information on ice conditions offshore northern Alaska. J. Brueggeman of Ebasco Environmental and M. Gallagher of COPAC provided bowhead and gray whale sighting information collected during site specific monitoring studies. Our thanks to all.

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ACRONYMS AND ABBREVIATIONS

ACW	Alaskan Coastal Water
ADC	American Digital Cartography
ADFG	Alaska Department of Fish and Game
BE	Belukha
BH	Bowhead Whale
BS	Bearded Seal
BSW	Bering Sea Water
CPUE	Calves Per Unit Effort
CT	Unidentified Cetacean
GARR	Gross Annual Recruitment Rate
GNS	Global Navigation System
GW	Gray Whale
IDL	International Date Line
IWC	International Whaling Commission
MMS	Minerals Management Service
MLR	Multiple Linear Regression
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NOSC	Naval Ocean Systems Center
NTIS	National Technical Information Service
Ocs	Outer Continental Shelf
PN	Unidentified Pinniped
PR	Polar Bear
RCW	Resident Chukchi Water
RS	Ringed Seal
s.d.	Standard Deviation
SPUE	Sightings Per Unit Effort
SR	Sighting Rate
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WPUE	Whales Per Unit Effort
WS	Walrus

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EXECUTIVE SUMMARY

This report summarizes the 1991 investigations of the distribution, abundance, migration timing and route, behavior, and habitat relationships of endangered whales in the Alaskan Chukchi and western Beaufort seas (hereafter, study area). Data presented herein were collected during transect and search surveys flown in a specially modified Grumman Goose (model G21 G) aircraft over the study area from 20 September through 7 November. The Bering Sea stock of bowhead whales (Balaena mysticetus), estimated by the International Whaling Commission (IWC) to number 7,500 whales, was the principal species studied. The California-Chukotka stock of gray whales (Eschrichtius robustus), estimated by the IWC to number 23,859 whales, was also studied, with incidental sightings of all other marine mammals routinely recorded. Data collected during the 1991 study were subsequently compared to and integrated with the results of surveys conducted from 1982-90.

There were 27 sightings for a total of 32 bowhead whales in the study area from 29 September through 31 October 1991. Three bowheads were seen in September, and 29 whales were seen in October. The sighting of bowheads in the Chukchi Sea on 31 October was two days later than in prior years. Survey effort shifted from northern to southern Chukchi Sea waters on 1 November, but no bowheads were seen there. Biologists conducting monitoring studies near offshore exploration sites southwest of Point Barrow, Alaska reported seeing bowheads in the study area as early as 24 August, and the whales seen on 31 October were in the northeastern portion of the study area, indicating that the migration period likely extended beyond the limits of the survey period.

There were 20 sightings for a total of 26 gray whales in the study area in 1991, from 22 September to 7 October. Gray whale distribution along the Chukchi coast was similar to, but not comprehensive of, past years. Although fewer in number, gray whales were seen offshore in the vicinity of Hanna Shoal (ca. 180 to 210 km northwest of Barrow) as in 1986-87 and 1989, and for the first time roughly 95 km northwest of Point Barrow.

Over ten survey seasons (1982-91), there were 267 sightings for a total of 552 bowhead whales in the study area. The earliest sighting was 18 September 1983 in the western Beaufort Sea and latest sighting was on 31 October 1991 in the north-central Chukchi Sea. Bowheads were often seen on the first and/or last survey from 1982-91, so these dates cannot be inferred as an absolute period for bowheads in the study area. Highest cumulative bowhead relative abundance was calculated for survey block 12 near Point Barrow, with highest annual indices in 1984 and 1989 coincident with bowheads feeding there. Comparatively high cumulative relative abundance was also calculated for survey blocks 13 and 18, west and southwest of Point Barrow. Estimates of bowhead whale density for 1982-91 are presented in Appendix B.

Patterns of distribution and swimming direction for 1982-91 indicate bowhead whales migrate westerly (272 °T, p< 0.001) close to shore between Smith Bay and Point Barrow, then most whales swim southwest (248 °T, p< 0.001) from Point Barrow across the Chukchi Sea. The principal migration route is roughly 1 to 30 km offshore between Barrow and Wainwright, extending to roughly 120 km offshore northwest of Icy Cape. However, a few bowhead sightings north of 72" N latitude suggest that some whales do not swim southwest after passing Point Barrow, but maintain a northwesterly heading past Point Barrow, or enter the study area from the north and cross the northern Chukchi Sea. Oscillations in daily rSI sighting rates indicate that bowhead migration timing into the Chukchi Sea begins in mid-September with an early component (SR = 1.43-2.02), peaks in early- to mid-October (SR = 1.69-3.88), with a few whales migrating through in late October (SR=0.36-1 .15).

Over ten survey seasons (1982-91), there were 167 sightings for a total of 424 gray whales in the study area during September and October. Relative abundance was highest in nearshore blocks near Point Hope and Point Barrow. The majority of gray whales (84%, n= 358) seen were feeding, usually in coastal blocks 13, 17 and 24. Offshore, feeding gray whales were seen in blocks 14 and 14N in 1986-87, 1989 and 1991, near the boundary of Hanna Shoal. Gray whales were usually (93%, n =394) in open water (O-1 0% ice cover), although gray whales were seen in ice cover up to 90%.

There were 120 sightings for a total of 475 belukhas (Delphinapterus leucas) in the study area in 1991. Belukhas were dispersed relatively nearshore southwest of Point Barrow and well offshore north and west of Point Barrow. Swimming direction was significantly clustered about 285" T in the western Beaufort Sea and about 233" T in the Chukchi Sea. There were 487 sightings for a total of 3,972 belukhas in the study area over ten survey seasons (1982-91). Cumulative (1982-91) relative abundance indices were two to five times higher for Chukchi Sea survey blocks north of 72" N than for areas further south.

There were 245 sightings for a total of 7,573 walruses in the northern Chukchi Sea during the 1991 study period, with most animals associated with the ice edge in the northern portion of the study area. There were 21 sightings for a total of 25 bearded seals, 3 sightings for a total of 6 ringed seals, one sighting of one ribbon seal, and 304 sightings for a total of 1,312 unidentified pinnipeds in 1991. Especially large aggregations (>800) of unidentified pinnipeds were seen in northwest Kotzebue Sound on 2 November 1989 and 5 November 1991.

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INTRODUCTION

The Outer Continental Shelf (OCS) Lands Act (67 Stat. 462) established Federal jurisdiction over the submerged lands of the continental shelf seaward of state boundaries in 1953, and charged the Secretary of the Interior with responsibility for administering minerals exploration and development of the OCS. In keeping with the National Environmental Policy Act (1969), the Marine Mammal Protection Act (1972) and the Endangered Species Act (1973), the OCS Lands Act Amendments (1978) established a management policy that included studies in OCS lease sale areas to ascertain potential environmental impacts of oil and gas development on OCS marine coastal environments. The Minerals Management Service (MMS) is the agency responsible for these studies and for the leasing of submerged Federal lands.

Oil and gas lease sales for the Chukchi Sea were held in May 1988 (Sale 109) and August 1991 (Sale 126), with a third sale (Sale 148) tentatively scheduled for 1996. Lessees were advised in each 'Notice of Sale' that the MMS intends to continue a monitoring program in the Chukchi Sea for whale species listed as endangered during exploration activities. In September 1989, the MMS awarded the Maritime Services Division of Science Applications International Corporation (hereafter SAIC; formerly SEACO/SAIC) a 3-year contract to monitor the distribution of endangered whales, and secondarily all other marine mammals, in the Alaskan Chukchi and western Beaufort seas via aerial surveys. This report constitutes a summary of the results of the third year of field work under this contract. Although incorporated in this report, results for the 1989 and 1990 survey seasons are available in separate annual reports (Moore and Clarke 1990; Moore and Clarke 1991).

The Alaskan Chukchi and western Beaufort seas from the Bering Strait to 73° N latitude between 154°W and 169° W longitude (hereafter, study area) incorporates the Chukchi and Hope Basin OCS Planning Areas and a portion of the Beaufort Sea OCS Planning Area (Fig. 1). Several marine mammal species seasonally occur in this region. In fall, bowhead whales and gray whales, both Federally listed as endangered species

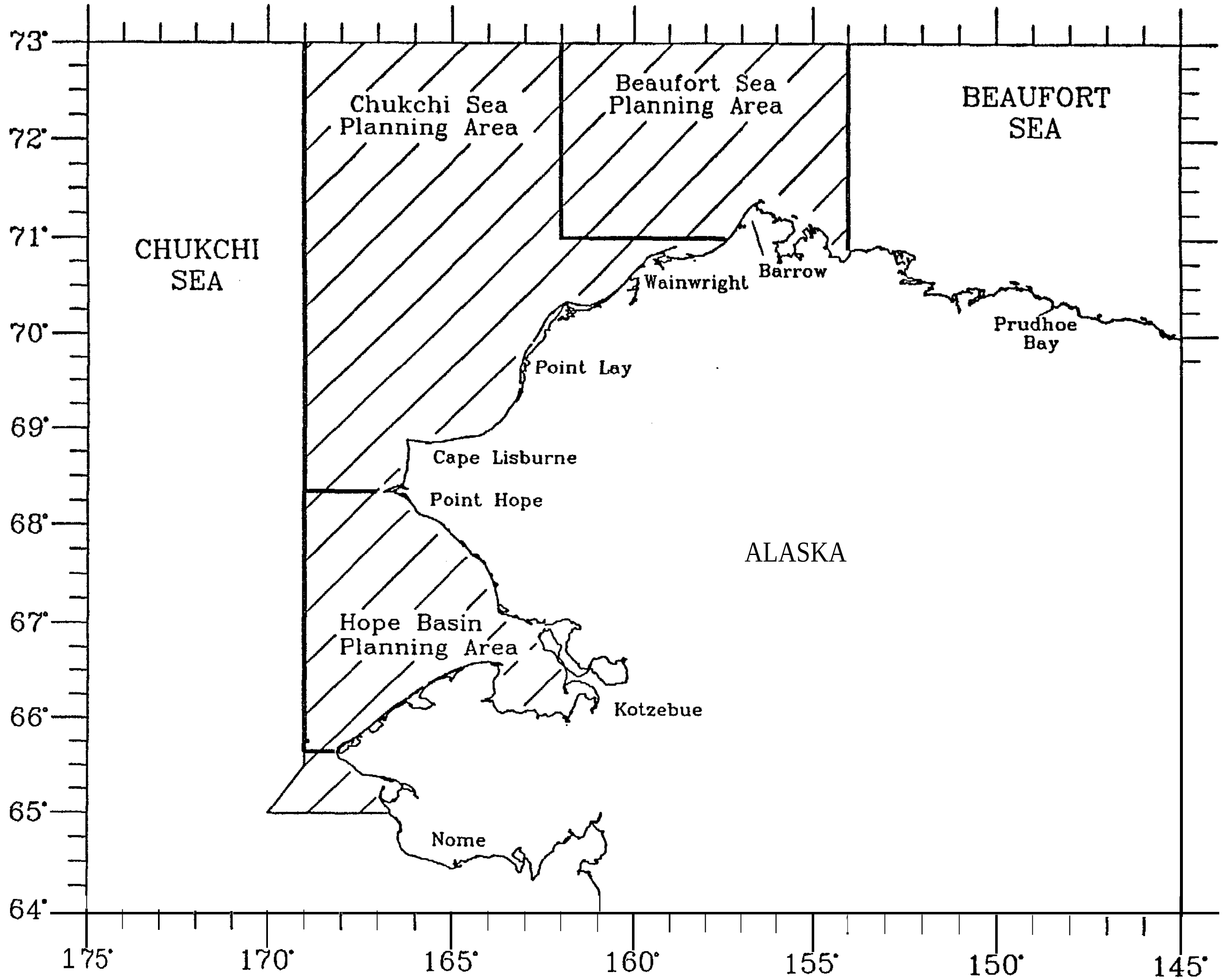


Figure 1. Chukchi Sea study area depicting the boundaries of the Chukchi and l-lope Basin OCS Planning Areas, and the westernmost portion of the Beaufort Sea OCS Planning Area.

(MMC 1992), co-occur at least in the northeastern portion of the study area (Moore et al. 1986a), while belukhas and several species of pinnipeds occur throughout the region (Ljungblad et al. 1988).

Bowhead whales were the species of principal interest during this study due to their endangered status and because they are the focus of an annual subsistence hunt by Alaskan Eskimos. Historically, bowheads had a nearly circumpolar distribution north of600 N latitude, but a long history of exploitation seriously reduced the number of whales in each of five geographically-identified stocks (Breiwick et al. 1981; Bockstoce and Botkin 1983; Bockstoce 1986; Moore and Reeves 1992). The Bering Sea stock, estimated by the International Whaling Commission (lWC) to contain 7,500 whales (IWC 1992a; MMC 1992) was the population monitored in this study. This stock annually migrates around western and northern Alaska between wintering areas in the northern Bering Sea and summer feeding grounds in the Canadian Beaufort Sea. The spring migration occurs from early April through June along open-water lead systems that annually develop relatively nearshore in the Chukchi Sea (Braham et al. 1984; Ljungblad et al. 1986b; Moore and Reeves 1992). The timing and route of the fall migration across the Chukchi Sea is less well defined. The migration occurs at least from late September through early November. It appears that most whales swim south-southwest after passing Point Barrow crossing roughly south of Herald Shoal in the central Chukchi Sea (Moore et al. 1986a; Moore and Clarke 1990, 1991), while a second component may take a more westerly course towards Herald and Wrangel islands before heading south along the Chukchi coast (Braham et al. 1984; Moore and Reeves 1992).

Gray whales are also classified as endangered, although estimates of their number in recent years indicate that the California-Chukotka stock has completely recovered from the commercial harvest of the late nineteenth century (Breiwick et al. 1988; MMC 1992). The Chukchi Sea represents the northernmost feeding ground for gray whales, although a few whales have been seen occasionally as far east as Herschel Island (Rugh and Fraker 1981; Wursig et al. 1983). Dense aggregations of feeding whales are common in the northern Bering Sea (Moore et al. 1986b), just south of the study area. Gray whales routinely feed along the Chukchi coast and in some years in the north-central Alaskan Chukchi Sea (Clarke et al. 1989). Furthermore, there is evidence that cows with calves segregate from the main population and are found more often along the Chukchi coast than among whales feeding in the northern Bering Sea (Moore et al. 1986b), similar to segregation patterns repotted for gray whales along the Chukchi coast (Bogoslovskaya 1986). These findings suggest that portions of the Chukchi Sea maybe important habitat for calf weaning, as well as feeding, for a population of whales that has recently expanded in number.

This report is a summary of results of aerial surveys for bowhead and gray whale distribution, relative abundance, density, migration and behavior in the Alaskan Chukchi and western Beaufort seas in accordance with the objectives outlined below. Belukha distribution, relative abundance, habitat relationships and behavior are also reported, as well as incidental information on all other marine mammals seen. Presentation of results for 1991 surveys precedes a review of data for years 1982-91. Flight tracks and descriptive captions, presented in Appendix A, provide an overview of 1991 daily survey effort and results. Annual density estimates for bowhead and gray whales in the study area for 1982-91 are provided in Appendix B. Finally, the proximity of bowhead and gray whale sightings to active exploratory drilling sites within the study area for 1989-91 is summarized in Appendix C.

Objectives

The primary objectives of the 1989-91 aerial surveys were to:

- determine seasonal distribution, relative abundance, migration timing and route, behavior, and habitat characteristics of bowhead and gray whales (hereafter, endangered whales) in or near existing and proposed Federal lease sale areas in the study area;
- derive estimates of relative and/or absolute abundance of endangered whales to describe spatial and temporal distribution patterns;

- describe behavioral characteristics of endangered whales as observed in or near existing and proposed Federal lease sale areas, with special emphasis on locating potential feeding areas and migration pathways;
- record locations and numbers of other marine mammals incidental to sightings of endangered whales;
- consult and coordinate field activities with other Federal agencies, state or local government organizations, or other endangered species researchers to maximize productivity of this study and minimize conflict with other resource uses;
- synthesize and further analyze endangered whale data obtained on surveys conducted in the study area since 1982 to describe temporal variation in fall sighting rates and to determine if any observed shifts in the migration routes have been induced by human activities.

METHODS AND MATERIALS

Project Rationale and Design

The timing and corridor of the fall bowhead migration across the Chukchi Sea is ill-defined compared to the spring migration (Ljungblad et al. 1986b; Braham et al. 1984; Moore and Reeves 1992). Further, bowhead whales feed in the western Beaufort Sea in fall of some years, but not in others (Ljungblad et al. 1986a; Borstad et al. 1987). Coastal and offshore areas in the northern Chukchi Sea are important feeding habitat for gray whales (Clarke et al. 1989), but their movements to and from these areas are poorly understood. Therefore, primary objectives of this project were to determine distribution and relative abundance, define fall migration timing and axis, and identify feeding areas for bowhead and gray whales in the study area. Related objectives included describing whale behaviors and recording their proximity, and reaction if any, to ongoing offshore exploratory drilling operations.

Aerial surveys conducted from Barrow and Kotzebue, Alaska, were designed to (a) determine when bowhead whales entered the Chukchi Sea, (b) monitor the progress of the bowhead migration through the study area, and (c) collect data on the broad-scale distribution, movements and behavior of bowhead and gray whales in the study area from late September through early November. Secondarily, the distribution, abundance and behavior of belukhas and incidental sightings of all marine mammals were recorded. Subsequently, data for all marine mammals were compiled with that collected on MMS-sponsored aerial surveys conducted in the study area by the Naval Ocean Systems Center and SEACO, Inc. from 1982-88 (Ljungblad et al. 1988), to provide the broadest possible data set for analyses. Aerial surveys to assess the status of the fall bowhead migration in the Alaskan Beaufort Sea east of 1540 W were conducted by MMS personnel from Deadhorse, Alaska (Treaty 1990, 1991, 1992). Daily coordination and data transfer between the Chukchi Sea and Beaufort Sea projects provided the MMS with real-time information required for implementation of lease stipulation and permit regulations.

Study Area and Aerial Survey Procedures

The study area included the western Beaufort Sea from 1570 W east to 1540 W and offshore to 730 N, and the Alaskan Chukchi Sea from 1570 W west to the International Date Line (IDL, approximately 168058'W) between 65040'N and 730 N. This area was divided into survey blocks (Fig. 2), such that one or, with favorable conditions, two blocks could be surveyed completely on one flight. Survey blocks 12 through 22 are identical to those súrveyed since 1983, facilitating comparisons of survey effort and relative abundance indices among years.

Two types of aerial surveys were conducted to accomplish the listed objectives:

1. Line transect surveys were flown in survey blocks to determine distribution and estimate relative and absolute abundance. Line transect is one available survey method from which statistical inferences can be made, provided the starting and turning points of the line are selected randomly (Cochran 1963). Survey blocks were divided into sections that were 30 minutes of longitude or 10 minutes of latitude wide, and each section was divided into 10 equal segments. Random transect lines were derived for each section by matching two numbers from a random numbers generator to the numbered segements and drawing a line between them. The same procedure was

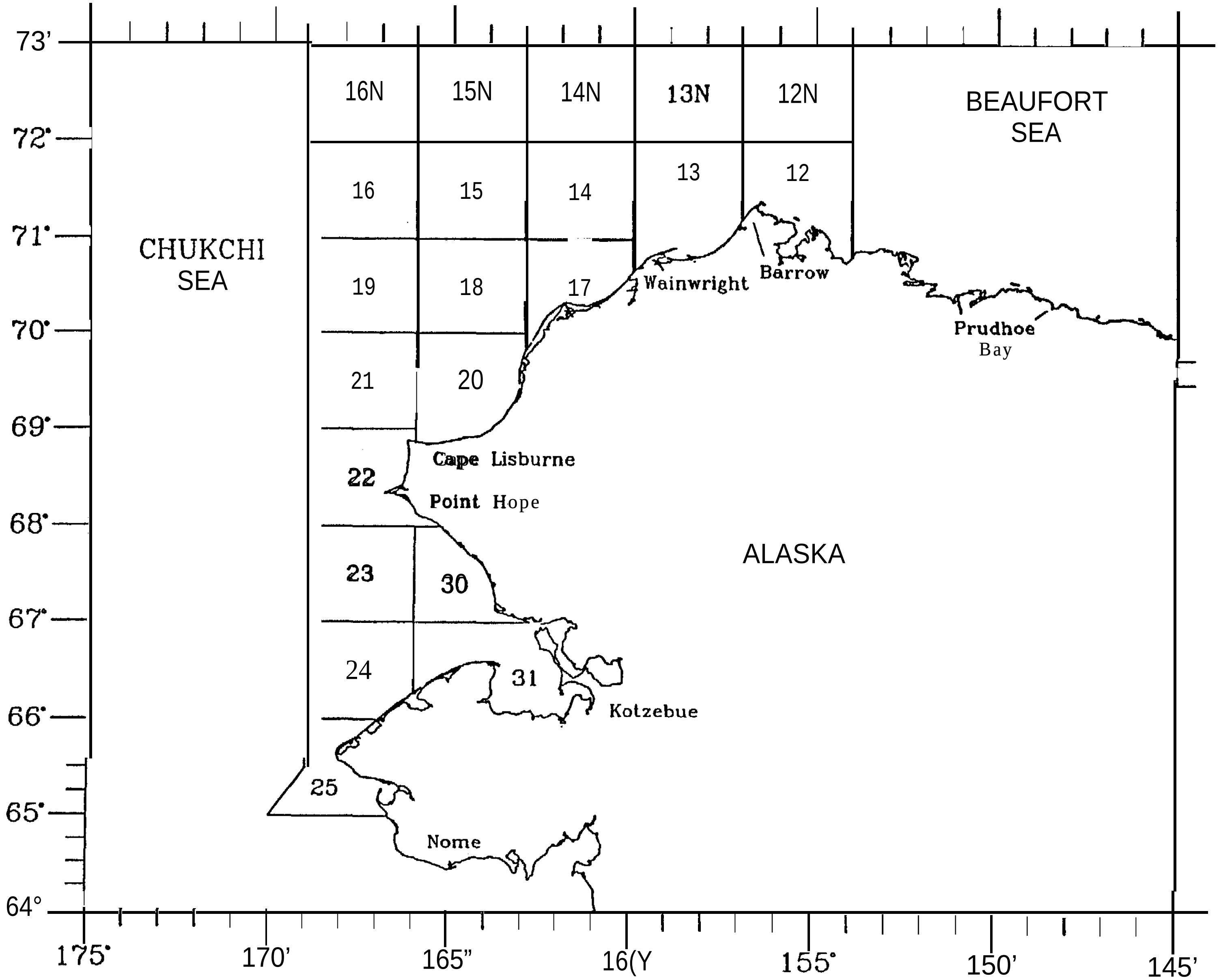


Figure 2. Survey blocks in the Chukchi Sea study area.

followed for each survey block section, then all transect lines were linked together with short connecting lines at the top and bottom. When bowhead or gray whales were encountered while surveying a transect line, the angle of declination to the sighting was measured with a clinometer when the aircraft was abeam of the whales, then the aircraft diverted from transect for brief periods (< 10 minutes) and circled above the whales to observe behavior, obtain accurate counts, and determine whether calves were present. Only whales seen initially, before diverting from the transect line, were considered random sightings (rSI). The rSI database was used for various statistical analyses, such as the line-fitting analysis to describe annual bowhead migration axes and for density calculations (Appendix B), to satisfy the assumption of a random sampling.

2. Search surveys were flown to locate whales and observe their behavior or when in transit to a survey block or a new base of operations. These surveys did not follow a preset paradigm, but instead were dependent upon weather, sea state, and ice conditions, or previous patterns of whale sightings.

The aircraft used for the surveys was a Grumman Turbo Goose (model G21 G) with a call sign of N780. The aircraft was equipped with a Global Navigation System (GNS) 500 that provided continuous position updating (0.6 km/h, ideally) and transect turning point programming. The aircraft cockpit was outfitted with four seats, each of which afforded excellent visibility through large side windows for the two principal observers and pilots. A long rectangular window behind the cockpit provided good visibility for the observer-recorder. Each observer had a clinometer to take angles on all whale sightings abeam of the aircraft which, along with altitude, were used to compute animal distance from the survey track line. Observers and pilots were linked to a common communication system. Surveys were flown at 305 m to 458 m altitude, at speeds of 222 to 296 km/hr. The higher altitudes were maintained when weather permitted in order to maximize visibility and to minimize disturbance to marine mammals.

A portable computer (Compaq LTE) was used aboard the aircraft to record and later analyze flight data. The data entry format consisted of 23 variables presented to the data recorder in menu format (Table 1: A-W). The first four variables (Table 1: A-D) were recorded automatically at each entry via an interface (AACO Model: Arinc 429 to RS 532) that connected the computer to the aircraft's GNS and radar altimeter. The data recorder then selected responses to the remaining variables, as required. Data for all variables were recorded whenever possible, and all entries were coded as to the type of survey being conducted (Table 1:E). During a typical survey flight (Fig. 3), a search leg was flown to the survey block, followed by a series of random transect legs that were joined together by connect legs, with search leg(s) conducted back to the base of operations. Sea state was recorded according to the Beaufort scale outlined in Chapman (1971). Ice type was identified using terminology presented in the Naval Hydrographic Office Publication Number 609 (1956), and ice cover was estimated in percent.

Data Analysis

Distribution and Relative Abundance

Observed bowhead and gray whale distribution was plotted for tri- and hi-monthly periods, and in relation to OCS oil and gas lease areas, for the survey season on maps generated by AutoCAD using a map digitized by the United States Geological Survey (Bauer 1989). Relative abundance indices were calculated as whales per unit effort (WPUE = no. whales/survey hour) per survey block for bowhead whales, gray whales and belukhas for periods corresponding to the distribution plots. Bowhead and gray whale density estimates were derived for survey blocks using strip transect methods and are presented in Appendix B. All whale sightings were entered into the distribution and relative abundance analyses, regardless of the type of survey leg being conducted when the sighting was made. Therefore, distribution scattergrams and WPUE represent the total sighting database in relation to the total survey effort. Density estimates, on the other hand, require that sightings used in their derivation be collected at random (Cochran 1963). Therefore, only sightings made on random transect legs (i.e., rSI) were used to derive density estimates; if no sightings were made on random transects within a survey block, density was not calculated for that block.

Table 1. Data entry format on the flight computer.

A. GMT
B. Latitude
C. Longitude
D. Altitude

E. Reason for Entry
- 0. flight aborted
- 1. sight on transect
- 2 sight off transect
- 3. sight search survey
- 4. position-on transect
- 5. position-on connect
- 6. position-cm search
- 7. start transect
- 8. end transect
- 9. divert transect
- 10. resume transect
- 11. deadhead

F. **Species**
- 0. no sighting
- 1. bowhead whale
- 2. gray whale
- 3. belukha
- 4. walrus
- 5. bearded seal
- 6. ringed seal
- 7. polar bear
- 8. ukn cetacean
- 9. ukn pinniped
- 10. orca
- 11. minke
- 12. fin
- 13. vessel

G. Sighting Cue
- 0. no cue
- 1. splash
- 2. blow
- 3. body
- 4. ice tracks
- 5. mud plumes
- 6. birds or fish
- 7. kill sight
- 8. oif sight

H. Habitat
- 0. open water
- 1. tide rip
- 2. on ice
- 3. on land

1. Behavior
- 0. unknown
- 1. dive
- 2. rest
- 3. swim
- 4. mate
- 5. feed
- 6. mill
- 7. spy hop
- 8. breach
- 9. roll
- 10. slap
- 11. u/w blow
- 12. cow/calf
- 13. dead
- 14. run
- 15. thrash

J. Size
- 0. unknown
- 1. calf of year
- 2. immature
- 3. adult
- 4. large adult
- 5. cow/calf pair

K. Total Number

L. Calf Number

M. **Clinomter Angle**

N. Swim Direction (°mag)

O. Swim Speed (kts)
- 0. unknown
- 1. still (o kt)
- 2. slow (c 1 kt)
- 3. medium (1-3 kts)
- 4. fast (>3 kts)

P. **Aircraft** Response
- 1. yes
- 2. no
- 3. unknown

Q. Repeat Sighting
- 1. yes
- 2. no
- 3. unknown

R. **Observer**

S. Weather
- 1. clear
- 2. partly cloudy
- 3. fog
- 4. overcast
- 5. precipitation
- 6. low ceiling
- 7. haze
- 8. glare

T. Visibility (left/right)
- 0. 0 km
- 1. <1 km
- 2. 1-2 km
- 3. 2-3 km
- 4. 3-5 km
- 5.5-10 km
- 6. unlimited

U. Ice Coverage ('%) and Type
- 0. no ice
- 1. floe
- 2. broken floe
- 3. pack
- 4. pack/floe
- 5. grease/new
- 6. shorefast
- 7. lead
- 8. bkn floe and new
- 9. new and bkn floe

V. **Beaufort Sea State**
- 0. B0 glassy c 1 kt
- 1. B1 lt ripple 1-3 kts
- 2.62 sml waves 4-6 kts
- 3. B3 sctrd caps 7-10 kts
- 4. B4 num caps 11-16 kts
- 5. B5 many caps 17-21 kts
- 6. B6 all caps 22-27 kts
- 7. B7 brkng waves 28-33 kts
- 8. B8 foam 3440 kts
- 9. N/A not applicable

W. **Water Color**
- 0. N/A
- 1. light blue
- 2. dark blue
- 3. light green
- 4. dark green
- 5. black
- 6. muddy
- 7. tideline

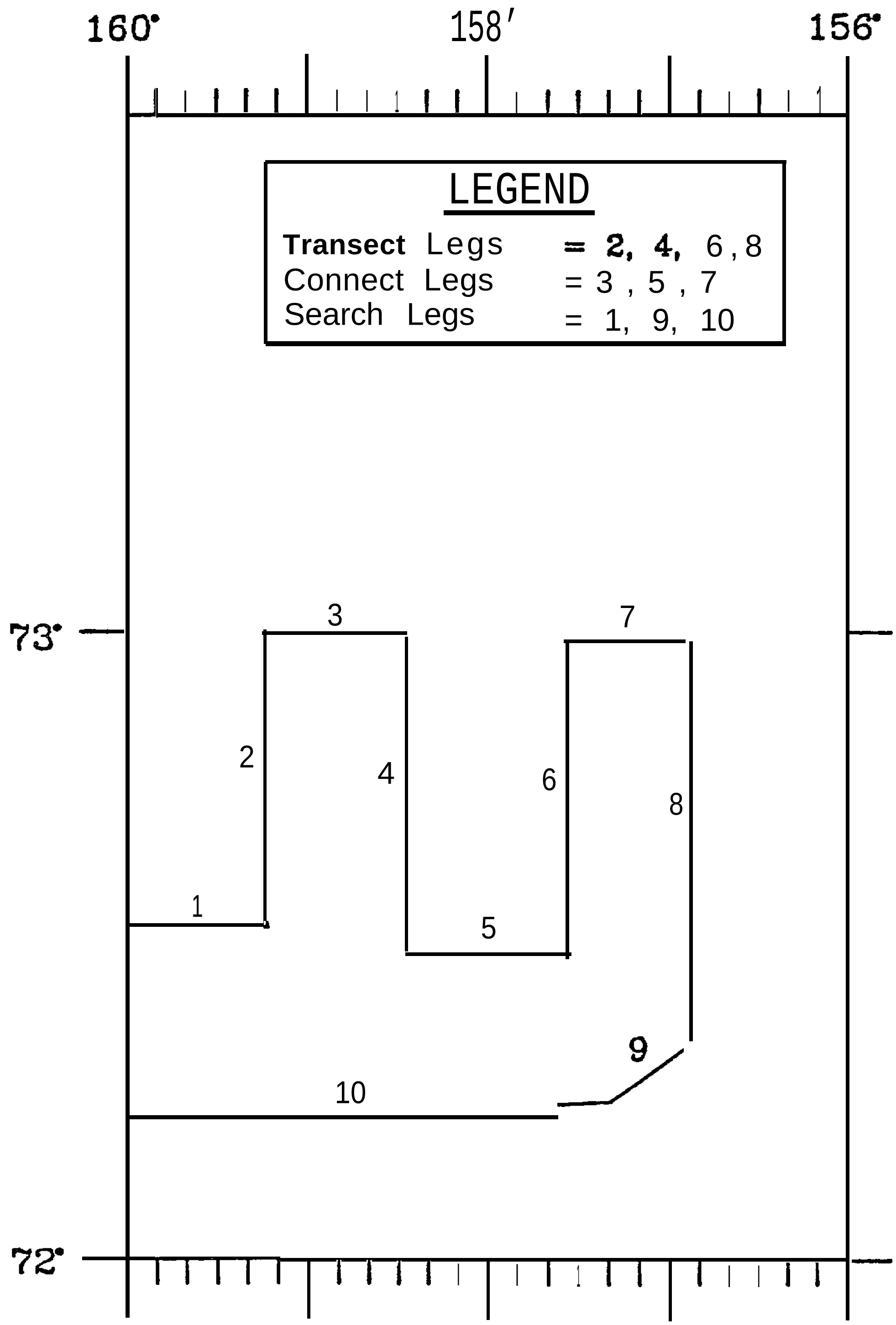


Figure 3. Example aerial survey flight track depicting transect, connect and search survey legs.

Migration Timing and Axis

The timing of the migration into the Chukchi Sea was described by daily rSI sighting rate (SR = rSI/transect survey time) from the cumulative 1982-91 database for survey blocks 12 and 12N (i.e., 154-157” W longitude). Temporal variation of annual survey effort in blocks 12 and 12N precluded the calculation of SR by year. The cumulative SR for the 154-157” W area was then compared to an expected SR derived from the assumption of a uniform temporal distribution using the G log-likelihood test (Zar 1984). The temporal occurrence of bowhead whales in the overall study area during the migration was analyzed as WPUE by calendar date using the full database. Both SR and WPUE analyses of migration timing are limited by the survey period, which coincided with the presumed main, but not entire, migration period.

One of the primary objectives of the study was to analyze the 1982-91 database for shifts in the fall bowhead migration route in the Alaskan Chukchi Sea. To meet this objective, the axis of each annual migration was described by fitting lines, using the method of least squares, to random sighting (rSI) locations west of Point Barrow (i.e., 156 °30’W longitude) and south of720 N. The standard base-60 latitude/longitude units were converted to base-10 (i.e., 71 °30’N = 71.5), prior to application of the line-fitting software (SPSS/PC +, Version 4.0) to the sighting locations. Also, latitude and longitude were treated as equal units of space, imposing a ‘flat-Earth’ perspective on the northeastern Alaskan Chukchi Sea. Inter-annual differences in migration axes (i.e. differences in line slope) among years was subsequently tested by analysis of covariance (ANCOVA), and differences between pairs of years by the Tukey test (Zar 1984). A random sampling of bowhead whale distribution was required for the statistical analyses, therefore only rSI were used for the analysis. Further, although a linear regression equation can be calculated for any data set ≥2, testing for a significant slopes requires at least three data (Zar 1984). Therefore, years with fewer than 3 random sightings west of Point Barrow were omitted from the analysis.

The line-fit protocol for defining and testing for differences among migration axes was selected because it is free of potential sources of measurement error inherent in analyses of sighting distance from shore (see Moore and Clarke 1992), and in analyses of the migration axis by sighting-depth association (see Treaty 1992; Moore and Reeves 1992). In 1991, a line fit analysis using Least Absolute Deviation (LAD) regression was performed using BLOSSOM software developed by Dr. P. W. Mielke Jr. and colleagues at Colorado State University (Mielke 1991). BLOSSOM is an interactive program for analyzing data with distribution-free statistical tests. IAD regression differs from least squares regression in that the sum of the absolute, not squared, deviations of the fit from the observed values is minimized. Depending on distributional pattern, power to detect location shifts in symmetric distributions with absolute distance statistics is greater than or equal to power with squared distance statistics (Biondini et al. 1988), which is why the IAD regression technique was investigated. However, the resulting linear equations were essentially identical to those using the more familiar least squares method, so the latter methodology was retained.

Additional description of migration corridors was provided by analyzing swimming direction for significant clustering around a mean heading using Rayleigh's test (Zar 1984). Swimming direction was analyzed for whales in the western Beaufort and northeastern Chukchi seas (east and west of 1570 W, respectively), and for whales north and south of 72" N in the northeastern Chukchi Sea. Because whales that are milling, feeding or resting often change headings several times while at the surface, swimming direction for whales exhibiting those behaviors was omitted from analyses. Significant difference in mean headings between data sets was tested using the Watson U^2 test for data containing tied values (Zar 1984).

Calf Sightings

Calf sightings were summarized in a table for 1991 and plotted for 1982-91. To determine if there was any pattern of temporal segregation, calf sighting rate (cSR = no. calves/survey hr) was derived for semi-monthly periods for the 1982-91 data set, Calf SR, derived using rSl only, was subsequently tested for significant difference among semi-monthly periods using chi-square test for proportions.

Behavior

Whale behaviors were cataloged into two types for purposes of discussion: migratory behaviors, including swimming and diving; and social behaviors (typically observed in groups), such as milling, feeding, cow-calf association, resting, displaying and mating **(Table 2).** Displays included breaches, spy-hops, tail and flipper slaps, rolls, underwater blows, and log-play. Swimming speed was subjectively estimated by observing the time it took a whale to swim one body length. An observed swimming rate of one body length/rein corresponded to an estimated speed of 1 km/hr, one body length/30 sec was estimated at 2 km/hr, and so on. Swimming speed and whale size were recorded by category (i.e., still, O km/hr; slow, O-2 km/hr; medium, 2-4 km/hr; or fast, >4 km/hr; and calf, immature, adult or large adult, respectively) rather than an absolute scale.

Habitat Relationships

Habitat associations were described as percentage of whales/ice cover class and percentage of whales/depth category. Ice cover classes were indexed to four ice condition categories: no ice (O-10?40 ice cover), light ice (11 -40% ice cover), moderate ice (41-70% ice cover) and heavy ice (71-100% ice cover). The expected frequencies of random sightings (rSI) in each ice condition was calculated based on random transect survey time, and tested using log-likelihood ratio analysis (Zar 1984). Bowhead whale distribution (1982-91) was related to published accounts of Chukchi Sea current patterns by determining the proportion of random sightings that were in water <37 m and ≥37 m (20 fathoms) deep, and comparing these ratios to the approximate availability of habitat in the two depth categories using chi-square for proportions analysis. The possible relationship between whale distribution and currents is inferred, as major currents in the Chukchi Sea are bathymetrically directed around shoals, where water depth is generally <37 m (Aagaard 1987; Stringer and Groves 1987; Paquette and Bourke 1981).

Table 2. Operational definitions of observed whale behaviors.

MIGRATORY:	
Swimming	Forward movement through the water propelled by tail pushes.
Diving	Change of swimming direction or body orientation relative to the water surface resulting in submergence; may or may not be accompanied by lifting of the tail out of the water.
SOCIAL:	
Milling	Whales swimming slowly in close proximity (within 100m) at the water surface.
Feeding	Whale(s) diving repeatedly in the same general area sometimes accompanied by mud streaming from the mouth and defecation upon surfacing; nearly synchronous diving and surfacing have been noted as have echelon formation surface feeding with swaths of clearer water noted behind the whales; and open mouth surface swimming.
Mating	Ventral-ventral orientation of a pair of whales often with at least one other whale present to stabilize the mating couple; often within a group of milling whales; pairs appear to hold each other with their pectoral flippers and may entwine their tails.
Cow-Calf	Calf nursing; calf swimming within 20 m of an adult.
Resting	Whale(s) at the surface with head, or head and back exposed, showing no movement; more commonly observed in heavy-ice conditions than in open water.
Displays:	
Rolling	Whale rotating on longitudinal axis, sometimes associated with mating.
Flipper-Slapping	Whale on its side striking the water surface with its pectoral flipper one or many times; usually seen in groups, sometimes when whale is touching another whale.
Tail-Slapping	Whale hanging horizontally or vertically in the water with tail out of water waving back and forth striking the water surface; usually seen in groups.
spy-Hopping	Whale rising vertically from the water such that the head and up to one-third of the body, including the eye, is exposed,
Breaching	Whale exiting vertically from the water such that half to neatly all of the body is exposed then falling back into the water, usually on its side, creating a large splash and presumably some sounds.
Underwater Blow	Exhalation of breath while submerged creating a visible bubble.

RESULTS

Environmental Conditions

Fall ice conditions in 1991 were moderate in the Chukchi Sea and heavy in the western Beaufort Sea (Fig. 4), which contrasted with the extremely light ice conditions encountered in 1989 and 1990 (Moore and Clarke 1990, 1991). In late September, ice cover in the study area was 99 percent new and broken floe north of 72" N, except between 157" and 1600 W where 99 percent ice cover was not encountered until 72 °40'N latitude. South of there, ice cover ranged from 10-50 percent in the western Beaufort Sea and 0-40 percent in the Chukchi Sea. The study area was completely ice-free south of 71° 15'N. In early October, ice cover increased to 10-50 percent broken floe in the Chukchi Sea nor&hof71030'N, but remained largely unchanged in the western Beaufort Sea. Low ambient air temperatures (10-1 3" F) and light winds (<10 kts) led to the freeze-up (95-99% new and broken floe ice) of the western Beaufort Sea and portions of the Chukchi Sea north of70050'N on 7 October, although a nearshore lead remained open **between** Point Barrow and Point Franklin. These conditions persisted until mid-October, when warmer air temperatures and stronger winds broke up the ice edge in the Chukchi Sea and pushed it north to about 71020'N in areas east of 1630 W longitude. West of 163°W the ice edge was even farther north, such that survey blocks 15, 15N, 16, and 16N remained ice-free. The western Beaufort remained covered with 95 percent new and broken floe ice. Conditions remained largely the same through late October, although nearshore areas south to 700 N were 25-50 percent covered with new ice. There was no ice in the southern Chukchi Sea except for portions of Kotzebue Sound.

These visual observations are supported by satellite data collected by the University of Alaska, Fairbanks. In late September, a tongue of ice extended south to approximately 700 45'N between 165° and 170" W; areas west of there were ice-free out to730 N (Fig. 4). The ice edge east of the ice-tongue was located between **71030** and 720 N in the Chukchi Sea and very near to shore in the western Beaufort Sea. Ice analysis showed that conditions remained similar until 8 October, when the tongue of ice advanced east towards the Alaskan coast, so that heavy ice (> 90%) covered most of the study area north of 71" N and east of 166" W. By mid-October, the heavy ice cover had

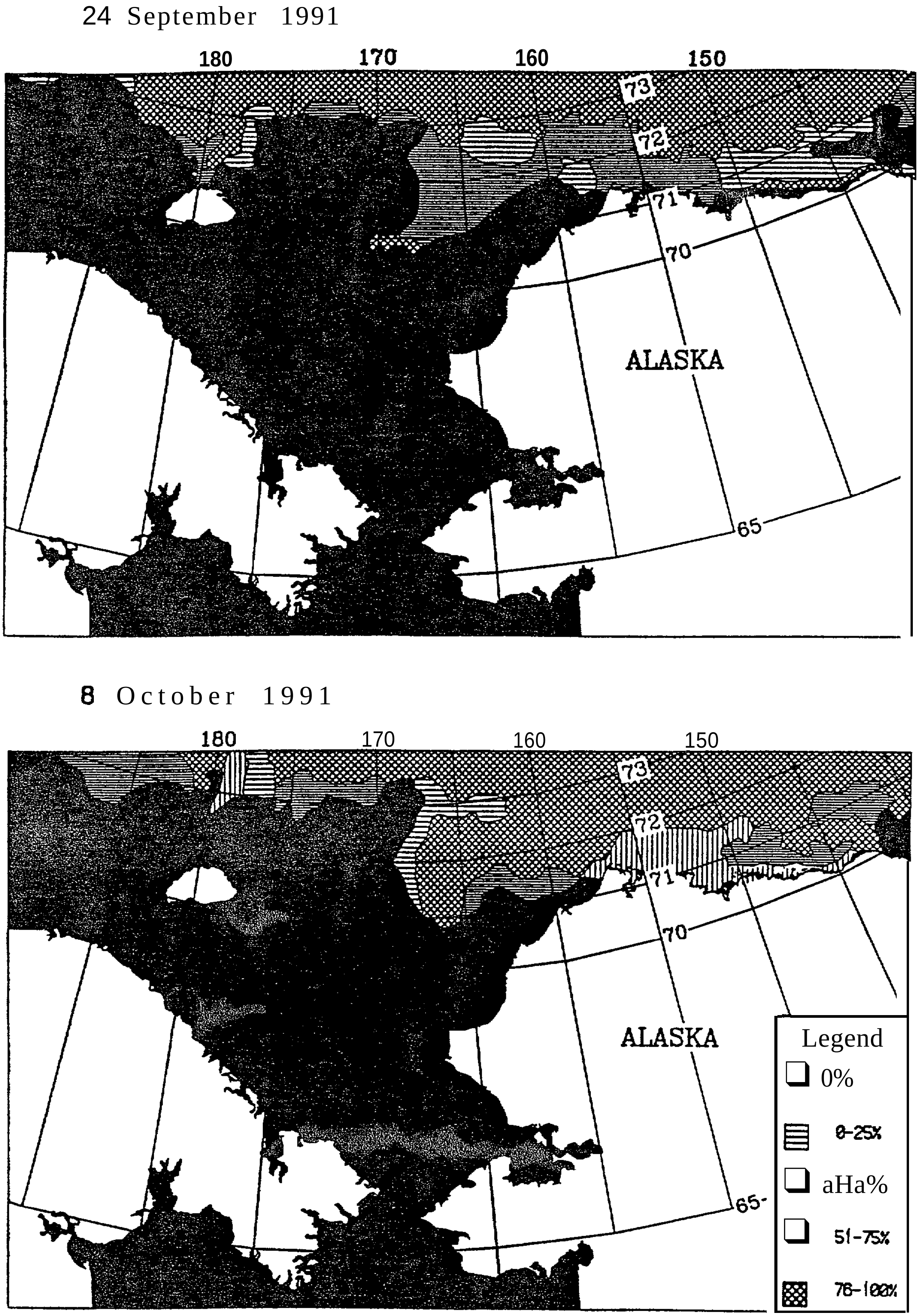
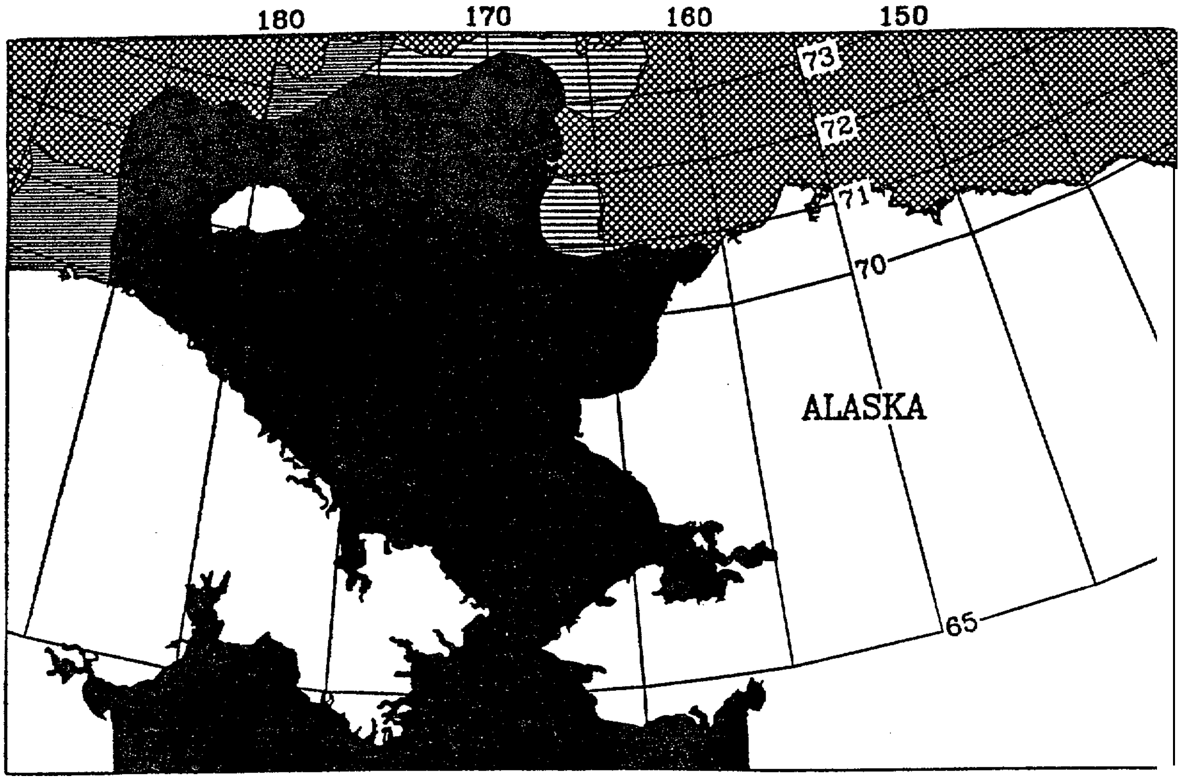


Figure 4. Ice concentration maps from the University of Alaska-Fairbanks Geophysical Institute: 24 September; 8 October;

15 October 1991



1 November 1991

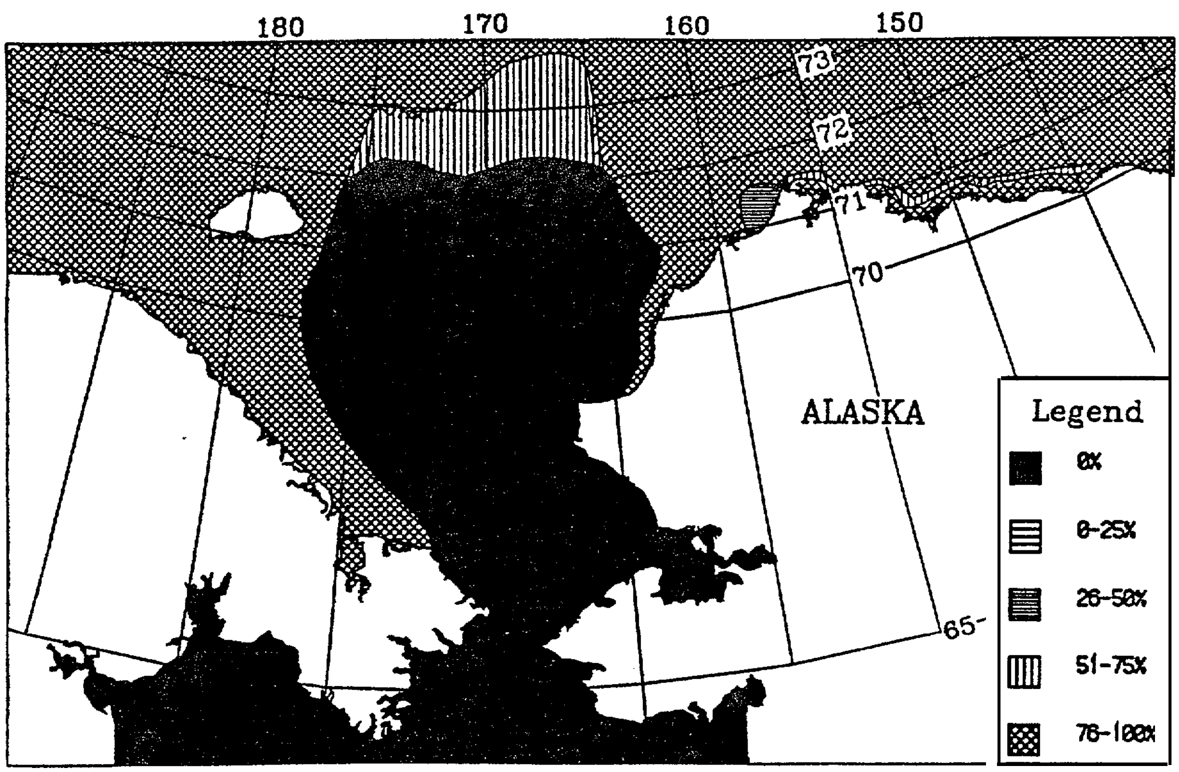


Figure 4 (contd). 15 October; and 1 November, 1991.

broken up somewhat, especially along the western edge, and areas west of 160” to 163” W were ice-free. The central portion of the Chukchi Sea remained ice-free through early November, while areas near to shore remained heavily covered (> 80%).

Survey Effort Summary

Nearly 134 survey hours were flown in 1991, with 79 percent [105.42 h) of this effort in the Chukchi Sea (i.e., waters west of 1570 W) and 21 percent (28.36 h) in the western Beaufort Sea (Table 3, Fig. 5). Poor weather, including high winds, fog and precipitation, prevented surveys on 14 days, mostly during the 20-30 September period and after 21 October. Required aircraft maintenance precluded flying on two days in early October.

Line transect surveys were conducted on most flights, with time spent on random lines alone accounting for 57 percent (76.75 h) of the total survey effort. Search surveys were flown enroute to, or when returning from, offshore survey blocks, or when transect surveys had to be curtailed due to low cloud ceilings (<GEL 300 m) or poor weather. Surveys were based out of Barrow from 20 September through 31 October to concentrate survey effort on northern and offshore survey blocks in the Chukchi Sea Planning Area, and out of Kotzebue from 1-7 November to focus survey effort in the Hope Basin Planning Area. Survey effort is depicted in 10- or 11-day periods (along with bowhead whale sightings) in Figure 6, and daily survey effort is summarized in Table A-1 in Appendix A.

Offshore Oil and Gas Exploration

Operations related to offshore exploratory drilling were conducted at three sites within the Chukchi Sea study area in 1991, but only one of these sites was active during the aerial survey field season (Table 4). The drillship Canmar Explorer ill and attendant ice breakers, supply vessels and helicopters worked at the Crackerjack site from 19 July to 31 August, prior to the commencement of aerial surveys. The drillship and attendant vessels moved to the Diamond site on 7 September where exploratory drilling continued until 5 October. This was the only active exploratory drilling conducted in the Chukchi Sea study area during the survey season. In addition, the SSDC MAT, a bottom-founded

Table 3. Summary of flight effort conducted in the study area, 1991.

	September 20-30	October 1-1o	11-20	21-31	November 1-7	Total
Number of flights	7	9	7	6	4	33
Poor Weather (days)	4	0	2	5	3	14
Aircraft Maintenance (days)	O	1	1	0	0	2
flight Effort Summary						
Chukchi Sea						
Transect (km)	2489	3672	3687	3406	1315	14569
Connect (km)	197	644	537	573	161	2112
Search (km)	1053	1821	2242	2175	1763	9054
Transect (H)	10.31	15.30	15.16	13.50	5.12	59.39
Flight (H)	15.62	25.82	26.47	25.01	12.50	105.42
Beaufort Sea						
Transect (km)	1053	1576	1169	403	0	4201
Connect (km)	152	173	96	70	0	491
Search (km)	524	480	447	416	0	1867
Transect (H)	4.30	6.66	4.77	1.63	0	17.36
Flight (H)	7.44	9.65	7.14	4.13	0	28.36
Total						
Transect (km)	3542	5248	4856	3809	1315	18770
Connect (km)	349	817	633	643	161	2603
Search (km)	1577	2301	2689	2591	1763	10921
Transect (H)	14.61	21.96	19.93	15.13	5,12	76.75
Flight (H)	23.06	35.47	33.61	29.14	12.50	133.78

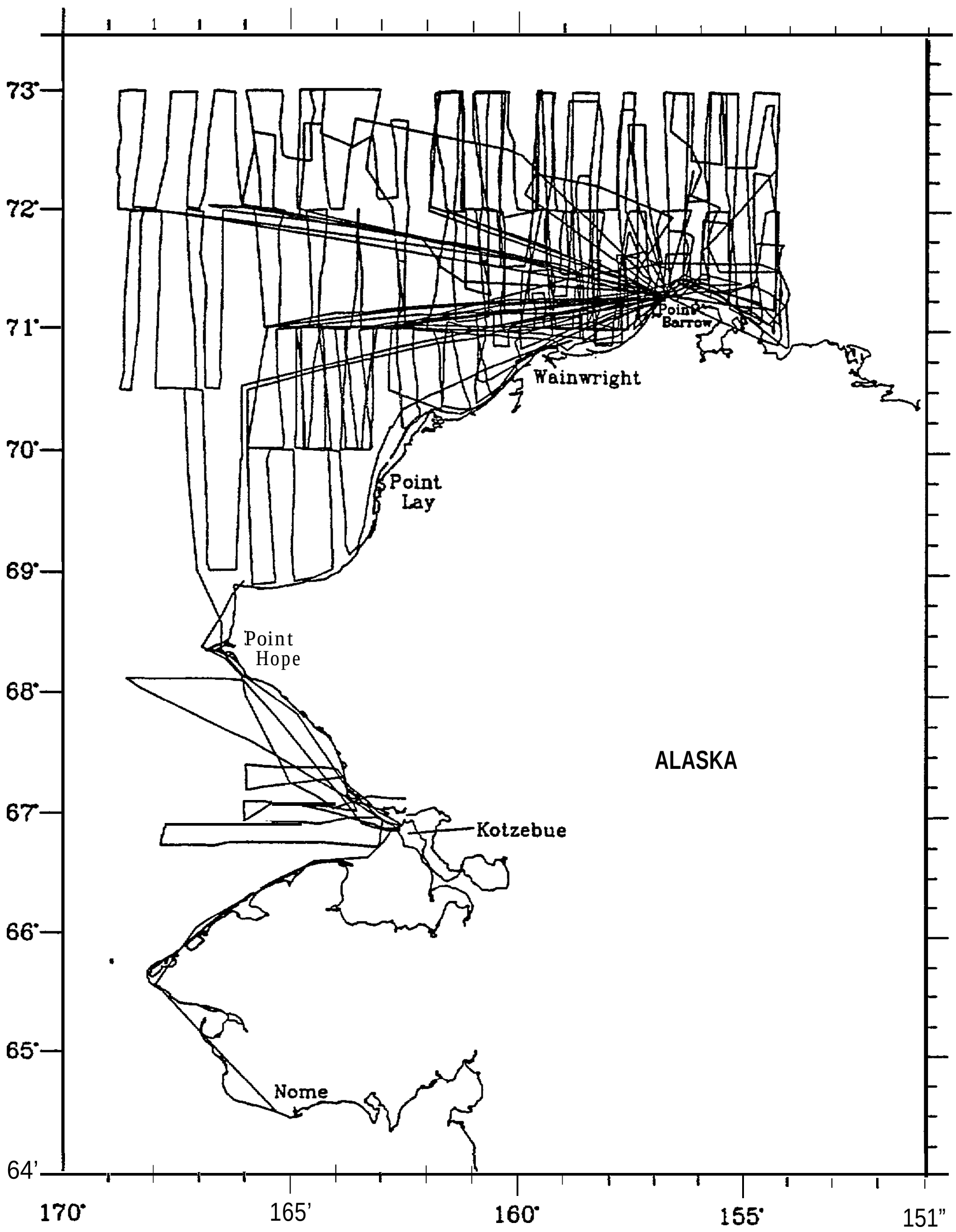


Figure 5. Composite flight tracks depicting 1991 survey effort.

Table 4. Summary of offshore oil and gas exploration activities in the study area, 1991. * Refers to surveys by this project; site-specific surveys were conducted by other researchers.

Site Name	Location	On-Site Dates	Survey Dates*
Crackerjack	71 °25'N, 165°32'W	19 Jul-31 Aug	None
Diamond	71020'N, 161 °41'W	7 Sep-5 Ott	9/24; 10/1 ; 10/2; 10/9; 10/22
Cabot	71019'N, 155°13'W	'warm standby' 28 Aug-1 NOV	9/21 ; 9/29; 10/3; 10/6; 10/9; 10/16; 10/20; 10/28

drilling structure, was moved to the Cabot site on 28 August and remained on 'warm standby' (i.e., no drilling was conducted) until 1 November, when exploratory operations commenced.

Surveys were conducted in the vicinity of the Diamond site on five occasions, and near the Cabot site on eight occasions (Table 4; Appendix C). No bowhead or gray whales were seen near (within 20 km) the Diamond site either during or after on-site dates. One bowhead was seen in the vicinity (18 km) of the Cabot site on 6 October (Appendix A: Flight 13; Appendix C). Bowhead whales, gray whales, walruses and seals were seen in the course of site-specific monitoring surveys conducted by other researchers in association with these offshore exploration activities (Brueggeman 1992; Gallagher et al. 1992). Bowhead and gray whale sightings from these surveys for the period 16 August through 5 November are summarized in Appendix C.

Bowhead Whale **(*Balaena mysticetus*)**

Distribution and Relative Abundance

There were 27 sightings for a total of 32 bowhead whales in the study area during the 1991 survey season (Fig. 6; Table A-2). Seven surveys were conducted from 20-30 September resulting in three sightings for a total of three bowheads seen roughly 83-120 km (45-65 nmi) northwest of Point Barrow (Appendix A: Flight 7). There were 13 sightings for a total of 18 bowheads from 1-10 October extending from waters north of Smith Bay in the western Beaufort Sea to north of Point Franklin (*ca.* 710 N, 159 °20’VV) in the northeastern Chukchi Sea. Although broad areas north and west of Point Barrow were surveyed during this period, bowhead sightings were confined to coastal waters (<~. 40 km), with the exception of three whales seen roughly 90 km from shore in block 12N. Only two bowheads were seen from 11-20 October, although extensive areas of the northeastern Chukchi Sea were surveyed. There were nine sightings for a total of nine bowheads from 21-31 October, all along the coast from Point Barrow to just north of Point Lay. No bowhead whales were seen in November.

Bowhead distribution in 1991 was generally similar to, but less extensive than, that observed in past years (Fig. 7). Although bowheads were seen north of 720 N in the Chukchi Sea in 1989 and 1990, none were seen therein 1991, and only two whales were seen north of 720 N in the western Beaufort Sea. Bowheads were seen within the boundaries of proposed oil and gas lease areas north and east of Point Barrow, but were predominantly east of lease area boundaries in the northeastern Chukchi Sea, as in past years. The distribution of whales along the northwestern Alaskan coast in 1991 was most similar to distribution observed in 1983 and 1988, both years of heavy ice conditions. Although 1991 ice conditions in the western Beaufort Sea were similar to those observed in 1983 and 1988, conditions in the northeastern Chukchi Sea were not, so ice can not be directly inferred as a reason for the observed nearshore distribution of whales there. The association of bowhead sightings and annual ice conditions is further discussed in the ‘Review’ section of this report.

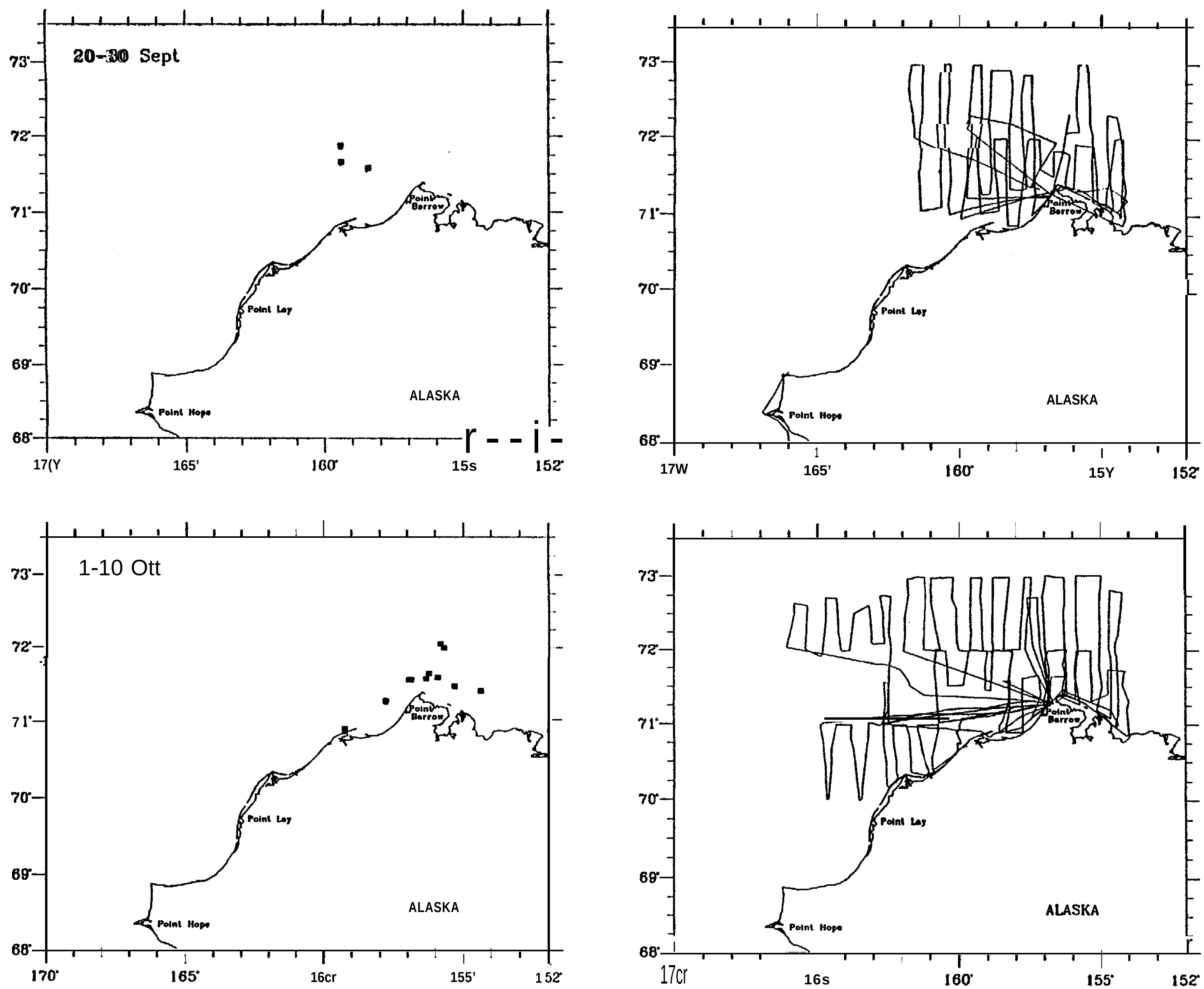


Figure 6. Bowhead whale distribution and composite flight tracks in 10 or 11-day periods during the 1991 survey season. Distribution maps depict 3 sightings for a total of 3 whales, 20-30 September; 13 sightings for a total of 18 whales, 1-10 October;

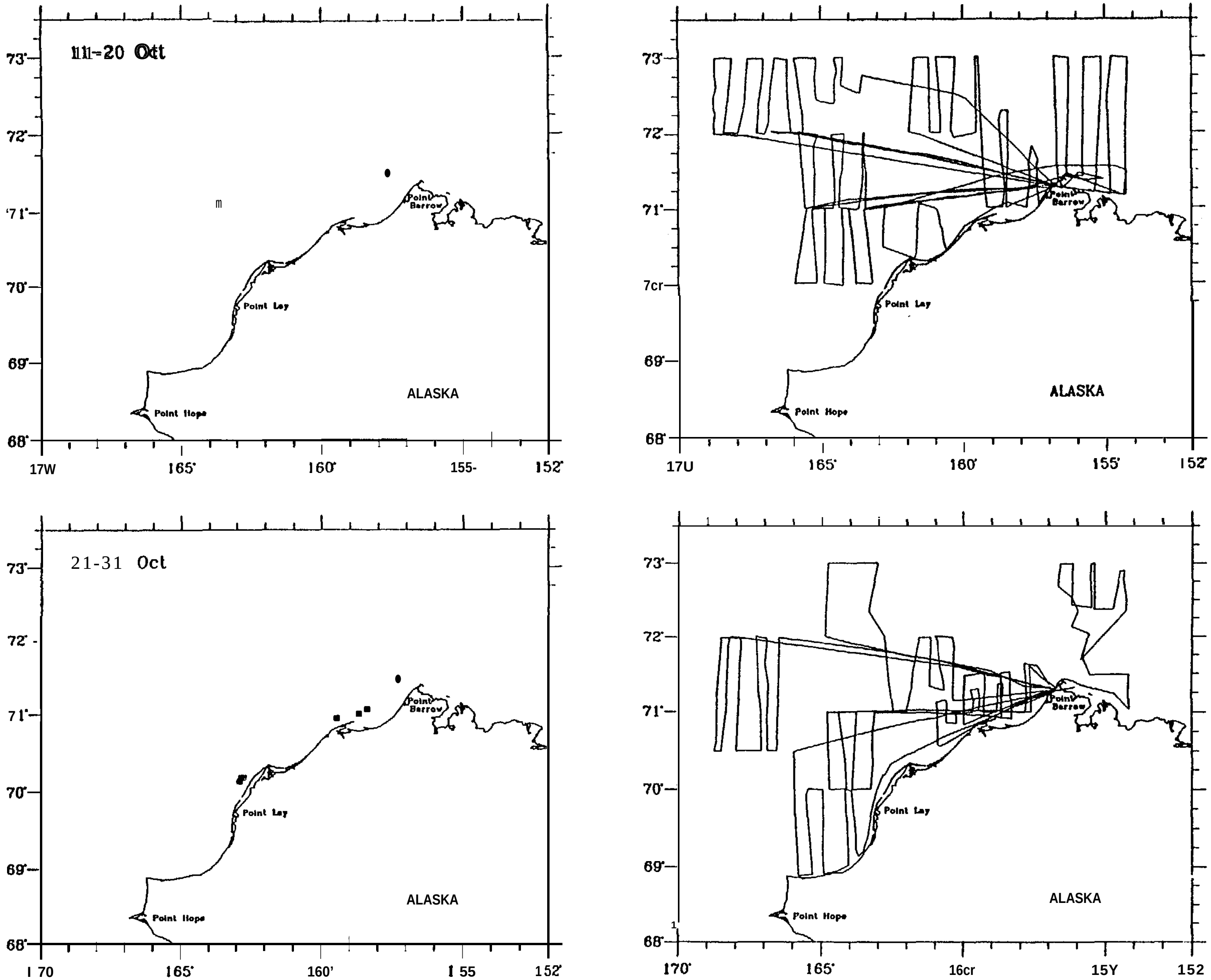


Figure 6 **(contd).** 2 sightings for a total of 2 whales, 11-20 October; and 9 sightings for a total of 9 whales, 21-31 **October,** 1989.

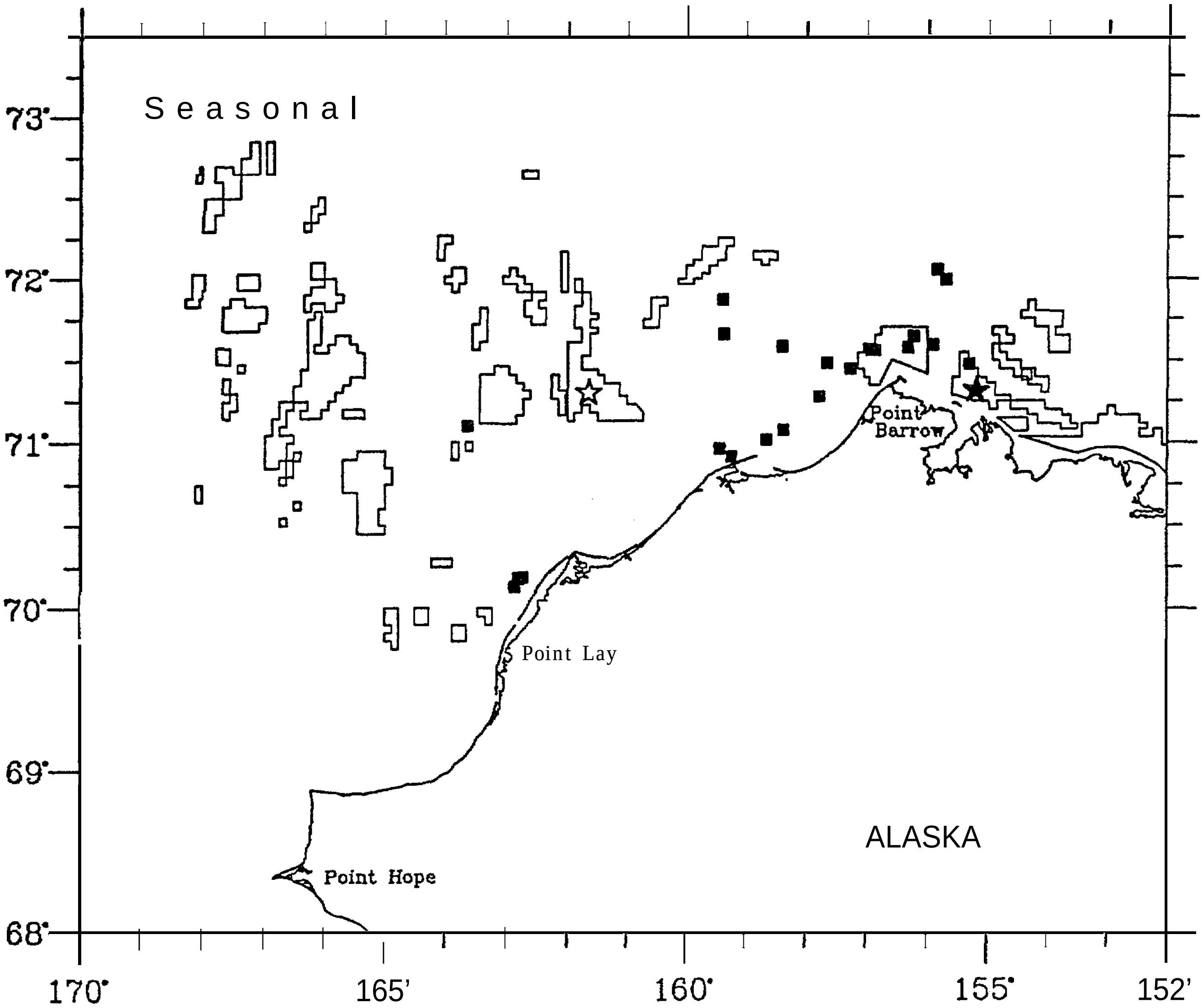


Figure 7. Distribution of 27 sightings for a total of 32 bowhead whales in relation to OCS lease areas and offshore exploration sites during the 1991 survey season. [☆ = 'Diamond' site; ★ = 'Cabot' site]

An index of relative abundance (WPUE =no. whales/survey hour) and a density estimate (no. whales/km^2) were calculated for bowhead whales by survey block. As described in the Methods section, all whale sightings were used in relative abundance calculations regardless of the type of survey being conducted. The calculation of density estimates using strip transect methods, however, requires that sightings be made while surveying a random transect leg (i.e., rSl) and that they occur within a predetermined distance from the aircraft (Hayne 1949; Hiby and Hammond 1989). Therefore, although abundance was calculated for any block in which bowheads were seen, density was calculated only for survey blocks in which whales were seen within 1 km on either side of the aircraft while surveying a transect line. Density estimates for 1991, and for years 1982-90 are presented in Appendix B.

Over the course of the field season, relative abundance was highest in block 12 (WPUE= 1.96) in early October and in block 17 (WPUE= 1.72) in late October (Table 5). Relative abundance elsewhere was low throughout the fall. In late September, bowheads were seen only in block 13 (WPUE = 0.41). In early October, whales were seen in block 12N (WPUE =0.79) and block 13 (WPUE=0.26), in addition to block 12 (WPUE = 1.96), indicating that a pulse of whales moved through the area with most whales passing through block 12. As mentioned above, only two whales were seen from 11-20 October, one in block 13 (WPUE=0.16) and one in block 15 (WPUE=0.23). In late October, bowheads were seen only in block 13 (WPUE=0.71) and block 17 (WPUE= 1.72).

Migration Timing and Axis

The bowhead migration extended from at least 29 September through 31 October. Bowhead whales were seen in the study area by other researchers before 29 September (see Appendix C), so it is likely that the migration through the study area began prior to the onset of the survey season. Also, the sighting of four bowheads on the last survey in the northeastern Chukchi Sea (Appendix A: Flight 29) indicates that migration through the study area probably extended beyond the survey period.

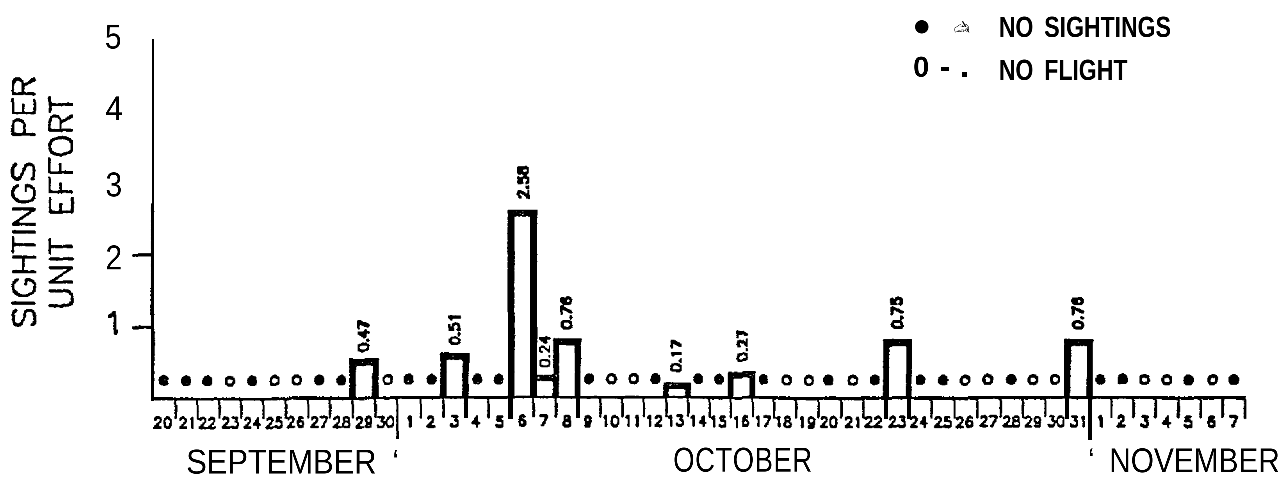
The temporal nature of the observed migration was generally similar to that of past years. The predominant peak in both sightings per unit effort (SPUE) and whales per unit effort (WPUE) occurred on 6 October (Fig. 8). However, unlike past seasons, there was no real ‘second peak’ to sighting rates in mid- to late October. Instead, sighting rates remained uniformly low through the remainder of the survey season.

Swimming direction was not significantly clustered about any heading in the western Beaufort Sea (Fig. 9). Whales were seen swimming southwest and northeast, with an average direction of 187” T. Swimming direction was significantly clustered about

Table 5. Bowhead whale relative abundance (WPUE=no. whales/survey hour) by survey block, 1991.

Block	20-30 Sept HRS	BH	WPUE	1-10 Ott HRS	BH	WPUE	11-20 Ott HRS	BH	WPUE	21-31 Ott HRS	BH	WPUE	1-7 Nov HRS	BH	WPUE	Total HRS	BH	WPUE
12	5.82	o	-	7.13	14	1.96	4.22	0	0	2.05	0	-	0.00	-	-	19.22	14	0.73
12N	1.62	0	-	2.52	2	0.79	2.92	0	0	2.08	0	-	0.00	-	-	9.14	2	0.22
13	7.27	3	0.41	7.56	2	0.26	6.31	1	0.16	7.07	5	0.71	0.36	0	0	28.57	11	0.39
13N	3.13	0	·	4.10	0	·	1.49	0	0	0.00	·	·	0.00	-	·	8.72	0	-
14	1.96	0	·	3.67	0	·	2.85	0	0	3.47	0	-	0.09	0	0	12,04	0	-
14N	1.83	0	-	2.90	0	-	2.01	0	0	0.08	0	-	0.00	·		6.82	0	-
15	0.00			0.57	0	·	4.26	1	0.23	1.06	0	-	0.00	·		5.89	1	0.17
15N	0.00			1.85	0		1.69	0	-	0.98	0	-	0.00			4.52	0	-
16	0.00	·		0.00		·	0.17	0	-	2.93	0	-	0.00	-	·	3.10	0	-
16N	0.00		·	0.05	0		3.21	0	-	0.00			0.00			3.26	0	-
17	0.00			2.96	0		1.13	0	-	2.33	4	1.72	0.27	0		6.69	4	0.60
18	0.00			1.98	0		3.24	0	-	2.65	0	-	0.38	0		8.25	0	-
19	0.00	·	·	0.00			0.00			1.51	0	-	0.72	0	-	2.23	0	-
20	0.00	·		0.00		·	0.07	0	-	2.93	0	-	0.00	·		3.00	0	-
21	0.00	·	·	0.00			0.00	·		0.00			1.38	0		1.38	0	-
22	0.56	0	·	0.00			0.00		·	0.00			0.77	0	·	1.33	0	“
23	0.00			0.00	·		0.00		·	0.00			0.48	0	·	0.48	0	-
24	0.00		·	0.00			0.00		·	0.00			0.87	0		0.87	0	-
25	0.00	·		0.00			0.00	·	·	0.00			0.67	0		0.67	0	-
30	0.87	0		0.00		·	0.00	·		0.00			3.57	0		4.44	0	-
31	0.00	·	·	0.00			0.00	·		0.00	-		2.57	0	·	2.57	0	-
Unblk	0.00	·		0.18	0		0.04	0	-	0.00	-		0.37	0		0.59	0	-
Total	23.06	3	0.13	35.47	18	0.51	33.61	2	0.06	29.14	9	0.31	12.50	0	·	133.78	32	0.24

1991



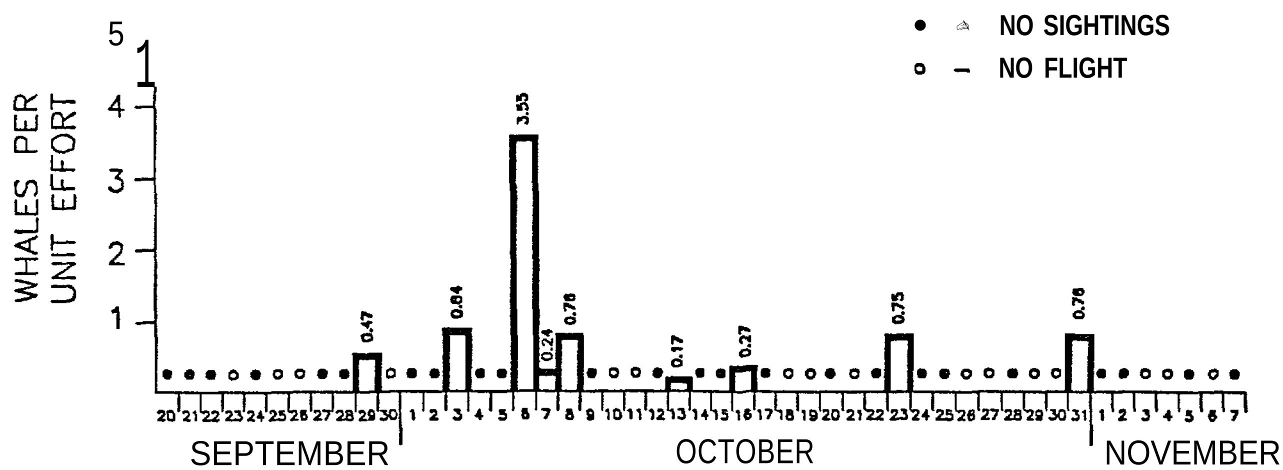
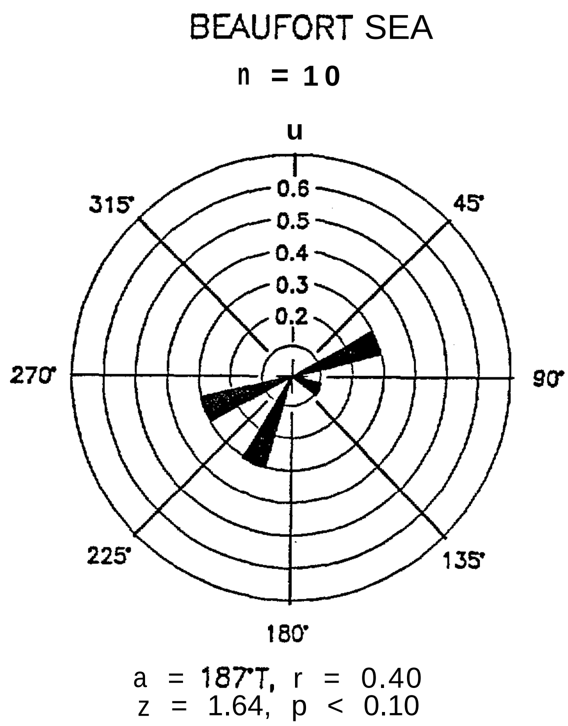


Figure 8. Daily bowhead whale sightings per unit effort (SPUE) and whales per unit effort (WPUE) in the study area, 1991.



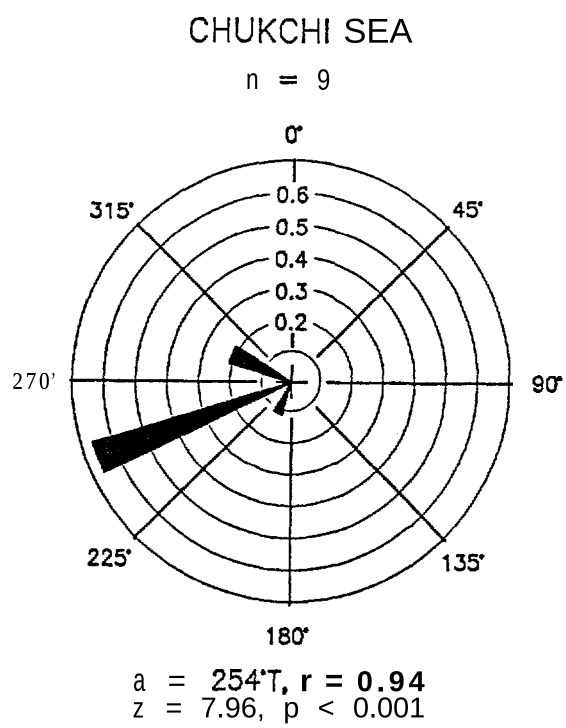


Figure 9. Bowhead whale swimming direction in the western Beaufort and northeastern Chukchi seas, 1991.

Table 6. Bowhead whale calf sightings, 1991.

Flight	Date	Position	No.	Comment
10	3 Ott	72°03.2'N 155" 49.2'W	1	swimming 85 'T, with large whale
10	3 Ott	71°38.8'N 156°12.9'W	1	resting, with large whale
18	13 Ott	71005.9'N 163 °37.6'W	1	swimming 2550 T, solitary, lunging out of water

a mean heading of 2540 T in the Chukchi Sea, indicating a southwest migration route across the Chukchi Sea, as described for previous years. Further description of the 1991 migration timing and axis is presented in the 'Review' section of this report.

Calf Sightings

Three bowhead calves were seen over the course of the season (Table 6). Two were seen in block 13 on 3 October (Appendix A: Flight 10), each near a large whale assumed to be the cow. One cow-calf pair was observed in a small open-water lead amid heavy ice, swimming slowly east and eventually diving under a pan of ice. They were briefly resighted in a nearby lead. These whales represent the northernmost bowhead whale sighting in 1991. The other cow-calf pair was resting at the surface at the time of sighting and did not move appreciably during the brief period of circling. A lone calf was seen on 13 October (Appendix A: Flight 18) swimming rapidly southwest in block 15. The calf was gray in color and had a distinctive white chin patch and small white tail chevron. A water disturbance was the sighting cue for this whale, as it continuously lunged out of the water creating a series of splashes in its wake. No other bowheads were seen during 10 min of circling over the calf. None of the calves responded to the aircraft.

Behavior

Most whales (63%) seen during the 1991 survey season were migrating (Table 7). No whales were observed milling or feeding in the study area, in contrast to prior years. The only social behaviors observed were displays (9%), resting (9%), and cow-calf associations (16Yo). Three whales were observed breaching on 23 October (Appendix A Flight 25) southwest of Barrow in survey block 13. The first breaching whale was in the company of another whale and both were first seen near a sea-surface interface of green/brown water. The breaching whale was the smaller of the two and remained in the green water breaching at about 40s intervals throughout the 20 minute observation. The second, larger whale was seen only once in the brown-colored water. This whale submerged without rolling or showing its flukes, and was not seen again during observation. Later on that flight, a second breaching whale was seen that originally was thought to be a re-sighting of the breaching whale seen earlier. Both whales were relatively small, although not calves, and had small round white spots on their chins. However, the distance and time between the sightings (42 km/2.01 h) seemed too great for this to have been the same whale. The third breaching whale seen that day was an adult with a large white chin patch. This whale breached only 4 times before swimming away.

Throughout the fall, most whales (54%) were judged to be swimming at medium speeds (Table 7). Whales not swimming at medium speed were either still [9%), swimming slowly (22%), swimming fast (6%), or had no swimming speed recorded (9%).

Habitat Relationships

Most bowheads (69%) were seen in water ≥37 m deep throughout the fall (Table 8). Depth at bowhead sightings ranged from 11-247 m in the western Beaufort Sea and from 15-123 m in the Chukchi Sea. Mean depth at bowhead sightings in the western Beaufort Sea (122.3 m) was significantly deeper ($t= 3.60$, $p <0.003$) than that in the Chukchi Sea (39.9 m). This reflects the deeper water present over the continental slope and Barrow Canyon in blocks 12 and 12N. In contrast, mean depth at bowhead sightings in the western Beaufort Sea was significantly shallower than that in the Chukchi

Gray Whale (Eschrichtius robustus)

Distribution and Relative Abundance

There were 20 sightings for a total of 26 gray whales in the study area from iate September through mid-October (Fig. 10; Table A-2). Eight gray whales were seen during late September in three distinct areas: nearshore between Barrow and Point Franklin, offshore west of Barrow in block 14, and north of 720 N in block 13N. Eighteen gray whales were seen from 1-10 October nearshore between Point Barrow and icy Cape and offshore northwest of Point Barrow in block 14N. Although no additional sightings were made during the survey season, two gray whales were seen 20 miles southwest of Barrow on 5 November (Appendix C). No gray whale calves were seen during the 1991 survey season.

Seasonal gray whale distribution (Fig. 11) was similar to, but not comprehensive of, past years. Although there were fewer total sightings, gray whales were seen in three of the four concentration areas identified previously: nearshore between Point Barrow and Icy Cape (l), and offshore in survey block 14 (2) and in survey block 14N (3) (Clarke et al. 1989). The gray whale seen in block 13N on 22 September (Appendix A: Flight 3) is the first sighting for that area. Notably, gray whales were not seen in the southern Chukchi Sea despite 10 h of survey effort there in early November.

Gray whale relative abundance was highest in block 14 (WPUE = 1.53) in late September and in block 17 (WPUE = 3.04) in early October (Table 10). Ten-day period and seasonal relative abundance indices were somewhat lower than in past years. For example, gray whale WPUE in survey block 14N was >2 from 20 September through 10 October in 1989, compared to 0-0.34 WPUE for the same period in 1991. Similarly, gray whale WPUE was 1.15 in survey block 13 from 20-30 September 1989, while in 1991 WPUE was only 0,41 for the same period. Finally, no gray whales were seen in survey blocks south of Point Hope where aggregations of feeding whales were seen in late October 1989. This may have been due to the restriction of 1991 survey effort to early November, however.

Table 7. Summary of bowhead whale behavior and swimming speed, 1991.

	20-30 Sept No. (%)	1-10 Ott No. (%)	11-20 Ott No. (%)	21-31 Ott No. (%)	Total No. (%)
BEHAVIOR					
Migratory					
Swim	2 (67)	14 (78)	1 (50)	3 (33)	20 (63)
Dive	o	0	0	1 (11)	1 (3)
Social					
Display	o	0	0	3 (33)	3 (9)
Rest	1 (33)	o	0	2 (22)	3 (9)
Cow-calf	o	4 (22)	1 (50)	o	5 (16)
TOTAL	3	18	2	9	32 (100)

SWIMMING SPEED					
Still 0 km/h	1 (33)	2 (11)	o	o	3 (9)
slow < 2 km/h	2 (67)	2 (11)	1 (50)	2 (22)	7 (22)
Medium 2-4 km/h	o	14 (78)	o	3 (33)	17 (54)
Fast > 4 km/h	o	0	1 (50)	1 (11)	2 (6)
Unknown	o	0	0	3 (33)	3 (9)
TOTAL	3	18	2	9	32 (100)

Table 8. Number and percent of bowhead whales in c 37 m and ≥37 m water depths, 1991.

Sea	<37 m	≥37 m	Range
W. Beaufort	2 (6)	14 (44)	11-247
Chukchi	8 (25)	8 (25)	15-123
Total	10 (31)	22 (69)	11-247

Table 9. Number and percent of bowhead whales in each ice cover class, 1991.

Ice Cover (??)	20-30 Sep No. (%)	1-1o Oct No. (%)	11-20 Ott No. (%)	21-31 Ott No. (%)	Total No. (%)
0-10	o	3 (16)	1 (50)	4 (44)	8 (25)
11-20	0	o	o	o	o
21-30	2 (67}	0	0	0	2 (6)
31-40	o	0	0	4 (44)	4 (13)
41"50	0	0	0	o	o
51-60	0	1 (5)	0	0	1 (3)
61-70	0	o	0	1 (12)	1 (3)
71-80	0	3 (17)	0	o	3 (9)
81-90	1 (33)	2 (11)	1 (50)	0	4 (13)
91-99	o	9 (50)	o	0	9 (28)
TOTAL	3	18	2	9	32

Sea in 1989 due to the aggregations of feeding and milling whales seen nearshore east of Point Barrow (Moore and Clarke 1990).

One-half of the bowheads seen were in heavy ice conditions (> 71% ice cover), with 28 percent seen in >90 percent ice cover (Table 9). As mentioned previously, ice was relatively heavy in early October, but became lighter by the end of the month. This is reflected in the differences in sighting ratios for whales in relatively light ice cover (O-10%) during 1-10 October (17%) compared to those seen during 21-31 October (44%). The number of rSl bowhead whales seen in each ice condition class was not significantly different from that expected based on random transect survey effort ($G = 1.66, p < 0.50$).

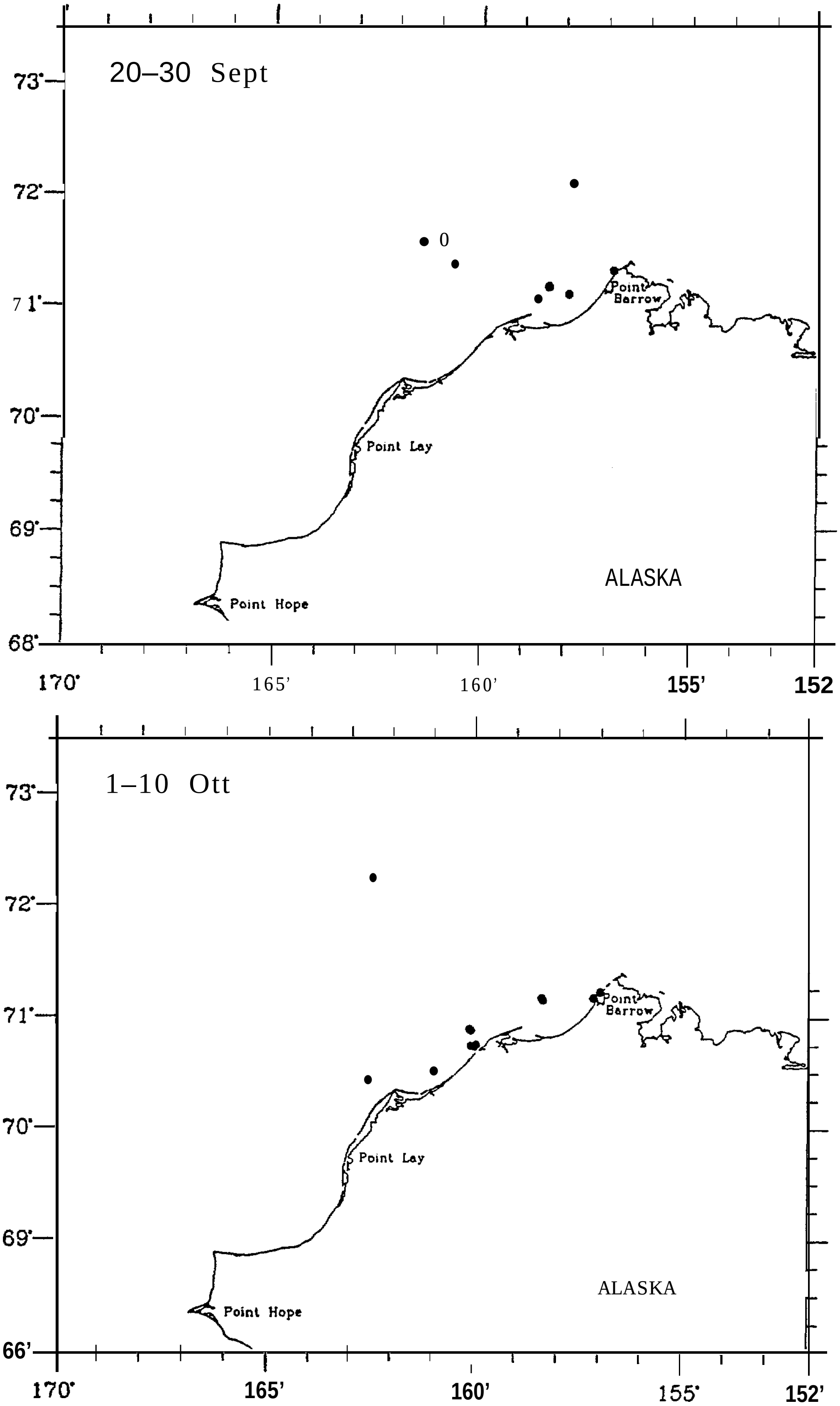


Figure 10. Distribution of gray whales depicting 8 sightings for a total of 8 whales, 20-30 September and 12 sightings for a total of 18 whales, 1-10 October, 1991.

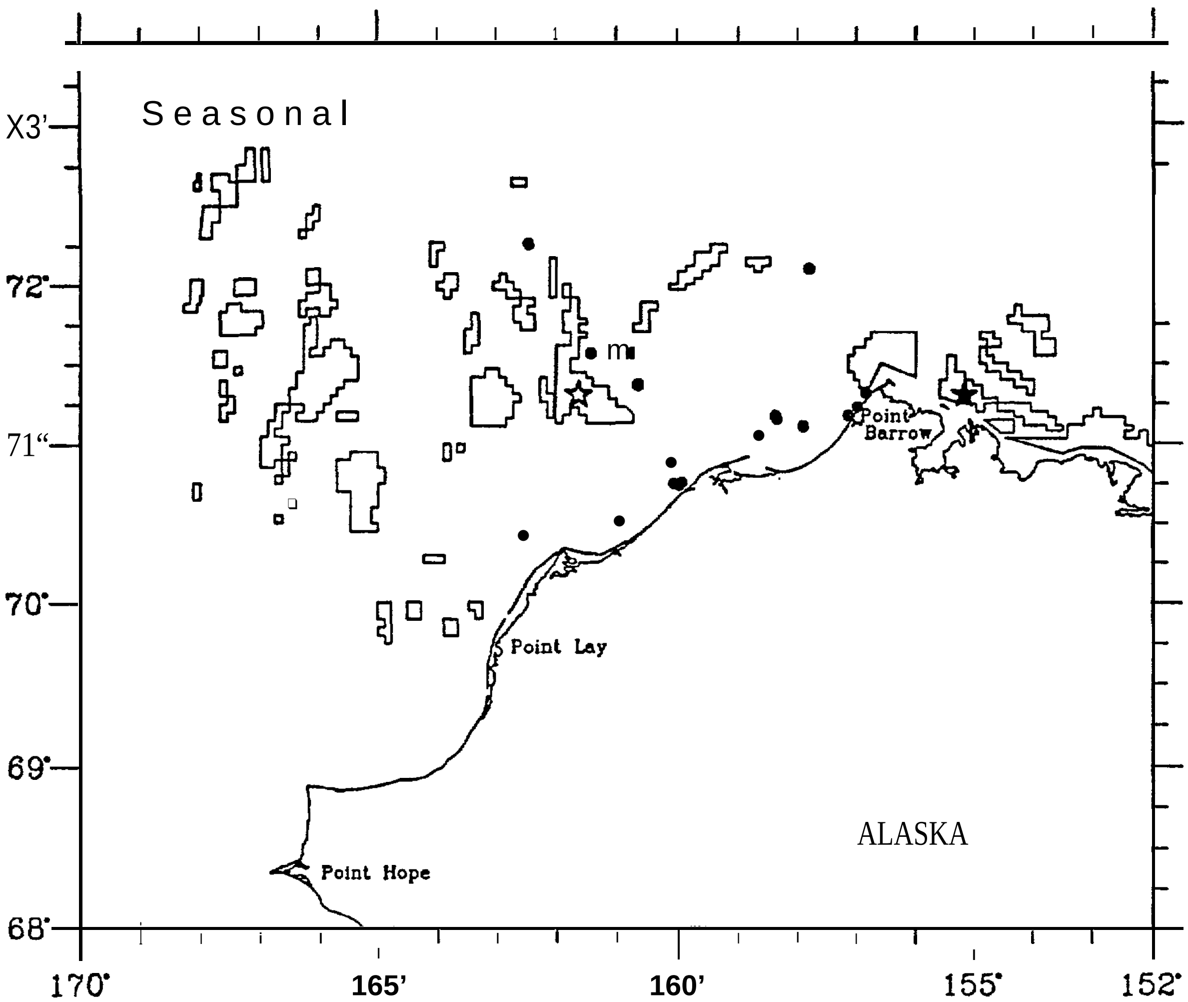


Figure 11. Distribution of 20 sightings for a total of 26 gray whales in relation to OCS lease areas and offshore exploration sites during the 1991 survey season. [☆ = 'Diamond' site; ★ = 'Cabot' site]

Migration Timing

The timing of the gray whale migration from the northeastern and north-central Chukchi Sea extended at least from 22 September to 7 October. Sightings of gray whales made by other researchers, however, indicate that gray whales were present in the study area prior to the start of the survey season and at least a few remained in the Chukchi Sea through early November (Appendix C). The lack of sightings after 7 October indicates that whales may have begun migrating south somewhat earlier than in past years. For example, gray whales were seen in the northeastern Chukchi Sea through 15 October and in the southern Chukchi Sea through 31 October in 1989. Gray whale migration timing is further discussed in the 'Review' section of this report.

Table 10. Gray whale relative abundance (WPUE = no. whales/survey hour) by survey block, 1991,

	20-30 Sept			1-1o Ott			11-20 Ott			21-31 Ott			1-7 Nov			Total		
Block	HRS	GW	WPUE	HRS	GW	WPUE	HRS	GW	WPUE	HRS	GW	WPUE	HRS	GW	WPUE	HRS	GW	WPUE
12	5.82	1	0.17	7.13	1	0.14	4.22	o	-	2.05	0	-	0.00		-	19.22	2	0.10
12N	1.62	0	-	2.52	0	-	2,92	0	-	2.08	0	-	0.00	-	-	9.14	0	-
13	7.27	3	0.41	7.56	7	0.93	6.31	0	-	7.07	0	-	0.36	0	-	28.57	10	0.35
13N	3.13	1	0.32	4.10	0	-	1.49	0	-	0.00	-	-	0.00		-	8.72	1	0.11
14	1.96	3	1.53	3.67	0	-	2.85	0	-	3.47	0	-	0.09	0	-	12.04	3	0.25
14N	1.83	0	-	2.90	1	0.34	2.01	0	-	0.08	0	-	0.00	.	-	6.82	1	0.15
15	0.00		.	0.57	0	-	4.26	0	-	1.06	0	-	0.00		-	5.89	0	-
15N	0.00	.		1.85	0	-	1.69	0	-	0.98	0	-	0.00		-	4.52	0	-
16	0.00	.	.	0.00			0.17	0	-	2.93	0	-	0.00		-	3.10	0	-
16N	0.00			0.05	0	-	3.21	0	-	0.00		-	0.00	.	-	3.26	0	-
17	0.00	-	.	2.96	9	3.04	1.13	0	-	2.33	0	-	0.27	0	-	6.69	9	1.35
18	0.00	.		1.98	0	-	3.24	0	-	2.65	0	-	0.38	0	-	8.25	0	-
19	0.00	-		0.00			0.00		-	1.51	0	-	0.72	0	-	2.23	0	-
20	0.00			0.00		.	0.07	0	-	2.93	0	-	0.00		-	3.00	0	-
21	0.00	.	.	0.00			0.00		-	0.00		-	1.38	0	-	1.38	0	-
22	0.56	0	-	0.00			0.00		-	0.00		-	0.77	0	-	1.33	0	-
23	0.00	-		0.00	-		0.00		-	0.00		-	0.48	0	-	0.48	0	-
24	0.00	.	.	0.00			0.00		-	0.00	.	-	0.87	0	-	0.87	0	-
25	0.00			0.00			0.00		-	0.00		-	0.67	0	-	0.67	0	-
30	0.87	0	-	0.00			0.00		-	0.00	.	-	3.57	0	-	4.44	0	-
31	0.00	-		0.00		.	0.00		-	0.00		-	2.57	0	-	2.57	0	-
Unblk	0.00	-		0.18	0	-	0.04	0	-	0.00		-	0.37	0	-	0.59	0	-
Total	23.06	8	0.35	35.47	18	0.51	33.61	0	-	29.14	0	-	12.50	0	-	133.78	26	0.19

Table 11. Summary of gray whale behavior, 1991.

	20-30 Sept No. (%)	1-1o Ott No. (%)	Total No. (%)
MIGRATORY			
Swim	1 (12)	6 (25)	7 (27)
SOCIAL			
Feed	7 (88)	12 (75)	19 (73)
TOTAL	8	18	26

Behavior

Gray whales were seen feeding (73%) and swimming (27%) during the fall season (Table 11). Feeding was inferred anytime whales were seen with mud plumes, which are billows of sediment created by feeding whales when they surface expelling sediments taken in during benthic foraging. Birds are often attracted to the mud plumes to feed on crustaceans expelled by the whales (Harrison 1979). The plumes, and the associated birds, provide excellent sighting cues which may bias data toward 'feeding' whales. Conversely, whales feeding on epibenthic prey may not create large plumes and may not be classified as feeding. The distribution of feeding whales was similar to that seen previously. Gray whales seen offshore in 1991 in blocks 14 and 14N were feeding, as evidenced by the presence of numerous mud plumes, although sightings were fewer when compared to 1986, 1987 or 1989. Apparently, gray whales use feeding areas near Hanna Shoal in some heavy ice years as well as in light ice years.

The majority of gray whales that were migrating were nearshore between Point Franklin and Icy Cape. The single gray whale seen offshore north of Point Barrow was also migrating. Swimming direction was significantly clustered about a mean heading of 260 °T ($n = 6$, $r = 0.79$, $z = 3.79$, $p < 0.02$). Whales that were feeding were not incorporated in this analysis because they often change directions several times within one surfacing.

Habitat Relationships

Gray whales were seen approximately c 1 to 205 km from shore in water 18 to 68m deep (x=33.8 m, 14.0 s.d., n =20). Most gray whales (84%, n =22) were seen in open water (0-10% ice cover). Two (8%) were in light ice conditions (11 -40% ice cover), and two (8%) were in heavy ice conditions (71-100% ice cover). The number of rSI gray whales seen in each ice condition category was not significantly different from that expected (log-likelihood G =7.46, p <0.1 O). Most feeding gray whales (84%, n =16) were seen in areas of O-10% ice cover. Of the three gray whales seen feeding in >10 percent ice cover, one was in 15 percent, one in 20 percent, and one was in 90 percent ice cover.

Other Marine Mammals

Belukha (Delphinapterus leucas)

There were 120 sightings for a total of 475 belukhas in the study area from 21 September to 24 October (Fig. 12; Table A-2). Belukha distribution in the western Beaufort Sea was similar to past years, with whales seen primarily in waters overlying the continental slope. Belukhas were broadly distributed across the northeastern Chukchi Sea north of Point Lay, in contrast to the bifurcated distribution pattern reported for earlier years (Moore and Clarke 1990). A peak-day count of 180 belukhas was made in block 16N on 14 October (Appendix A: Flight 19). No belukhas were seen in the southern Chukchi Sea.

Seasonal belukha abundance was highest in block 16N (WPUE = 55.21; Table 12), as a result of the aforementioned peak-day count there on 14 October. In late September, relative abundance was highest in block 13N (WPUE =24.60), shifting to block 14N (WPUE=9.31) in early October, to block 16N (WPUE=56.07) in mid-October, and block 16 (WPUE=2.39) by late October. Combined abundance in survey blocks 12N-16N (318 belukhas/32.46h = 9.80 WPUE) was over four times greater than that in survey blocks 12-16 (152 belukhas/68.82h = 2.21 WPUE). Belukha abundance was highest in late September and mid-October, relatively low in early October and extremely low in late October. This contrasts with abundance in 1989, which was highest in early October and remained relatively high throughout the season. Differences in both distribution and

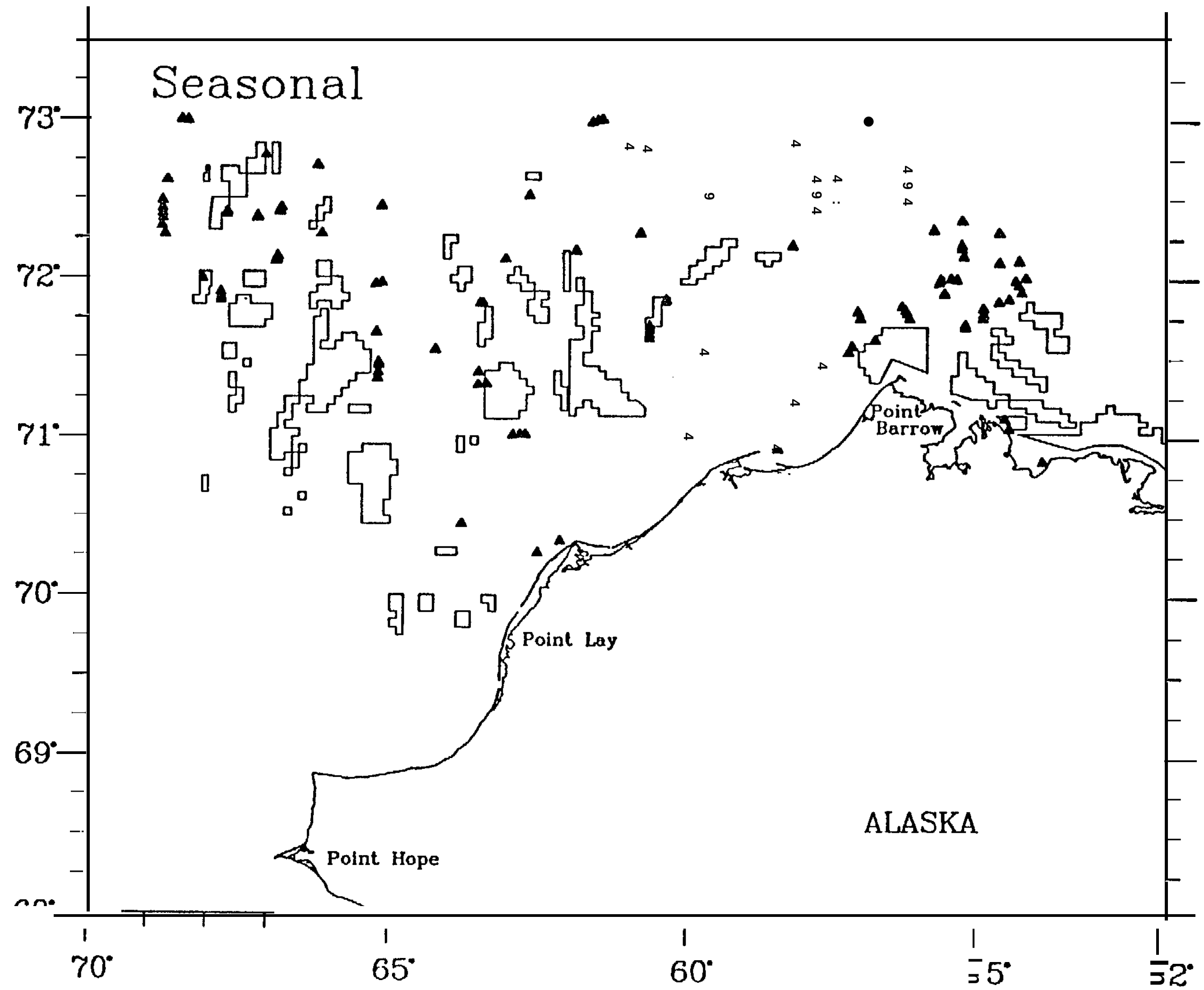


Figure 12. Distribution of 2○sightings for a total of 475 belukhas in relati○○ to OCS lease areas, 1991.

Table 12. Belukha relative abundance (WPUE = no. whales/survey hour) by survey block, 1991.

	20-30 Sept			1-1o Ott			11-20 Ott			21-31 Oct			1-7 Nov			Total		
Block	HRS	BE	WPUE	HRS	BE	WPUE	HRS	BE	WPUE	HRS	BE	WPUE	HRS	BE	WPUE	HRS	BE	WPUE
12	5.82	11	1.89	7.13	29	4.07	4.22	0	-	2.05	0	-	0.00	-	-	19.22	40	2.08
12N	1.62	15	9.26	2.52	9	3.57	2.92	0	-	2.08	0	-	0.00	-	-	9.14	24	2.63
13	7.27	31	4.26	7.56	28	3.70	6.31	7	1.11	7.07	0	-	0.36	0	-	28.57	66	2.31
13N	3.13	77	24.60	4.10	1	0.24	1.49	0	-	0.00	·	·	0.00	-	-	8.72	78	8.94
14	1.96	6	3.06	3.67	4	1.09	2.85	0	-	3.47	2	0.58	0.09	0	-	12.04	12	1.00
14N	1.83	6	3.28	2.90	27	9.31	2.01	0	-	0.08	0	-	0.00	·	-	6.82	33	4.84
15	0.00		·	0.57	1	1.75	4.26	24	5.63	1.06	2	1.89	0.00		-	5.89	27	4.58
15N	0.00			1.85	1	0.54	1.69	2	1.18	0.98	0	-	0.00		-	4.52	3	0.66
16	0.00		·	0.00			0.17	0	-	2.93	7	2.39	0.00		-	3.10	7	2.26
16N	0.00			0.05	0	-	3.21	180	56.07	0.00	·		0.00	·	-	3.26	180	55.21
17	0.00	·		2.96	2	0.68	1.13	0	-	2.33	0	-	0.27	0	-	6.69	2	0.30
18	0.00			1.98	0	-	3.24	0	-	2.65	3	1.13	0.38	0	-	8.25	3	0.36
19	0.00			0.00	·		0.00	-	-	1.51	0	· -	0.72	0	-	2.23	0	-
20	0.00		·	0.00		-	0.07	-	-	2.93	0	-	0.00		-	3.00	0	-
21	0.00	·		0.00			0.00	-	-	0.00	·		1.38	0	-	1.38	0	-
22	0.56	0	-	0.00			0.00	-	-	0.00			0.77	0	-	1.33	0	-
23	0.00			0.00			0.00	-	-	0.00		·	0.48	0	-	0.48	0	-
24	0.00		·	0.00		·	0.00	-	-	0.00	- -	-	0.87	0	-	0.87	0	-
25	0.00	·	·	0.00		·	0.00	-	-	0.00	·		0.67	0	-	0.67	0	-
30	0.87	0	-	0.00			0.00	-	-	0.00	·		3.57	0	-	4.44	0	-
31	0.00			0.00		·	0.00	-	-	0.00	-		2.57	0	-	2.57	0	-
Unblk	0.00			0.18	0	-	0.04	0	-	0.00	·		0.37	0	-	0.59	0	-
Total	23.06	146	6.33	35.47	102	2.88	33.61	213	6.34	29.14	14	0.48	12.50	0	-	133.78	475	3.55

abundance patterns may have been due to the constantly changing ice conditions throughout the fall.

The first belukhas were seen in the study area on 21 September (Appendix A: Flight 2) and the last on 24 October (Appendix A: Flight 26). There were four peaks in daily sighting rates, each separated by about a week (Fig. 13). The first peak occurred on 21 and 22 September (WPUE = 5.76 and 14.61, respectively), followed by peaks on 28 September (WPUE=36.47), 5 and 6 October (WPUE=7.91 and 7.10, respectively) and 14 October (WPUE=44.61).

Belukha swimming direction was significantly clustered about 285 'T ($p < 0.01$, $n=36$) in the western Beaufort Sea, and about 233 'T ($p< 0.001$, $n =77$) in the Chukchi Sea. There was no significant difference between cumulative heading frequencies in the two areas ($U^2=0.133$, $p <0.20$).

Belukhas were in water depths ranging from 2-2121 m, with mean depth at sightings in the Chukchi Sea (x=62.9 m, 49.1 s.d., n =82) significantly shallower than in the western Beaufort Sea (x=515.3 m, 681.7 s.d., n=38; t=4.09, $p<0.001$), due to the bathymetry of the two areas. Belukhas in the Beaufort Sea were offshore over the continental slope, while those in the Chukchi Sea were offshore over the shallower continental shelf.

Belukhas were seen mostly in open water (0-10% ice cover; 47%, n =222), light ice conditions (11-40% ice cover; 24%, n =11 5) or heavy ice conditions (71 -99% ice cover; 23%, n= 11 1), depending on when they were seen (Table 13). In late September, most belukhas (66%) were in light ice conditions, while in early October most (70%) were in heavy (71 -99%) ice conditions. In mid-October, 90 percent of all belukhas were seen in open water; most of these were seen on one flight in block 16N, which was completely ice-free. The few belukhas seen in late October were in open water. Significantly more rSI belukhas were seen in open water (n= 190) and light ice conditions (n =83) than expected based on the amount of random transect survey effort (G= 194.02, $p < 0.001$),

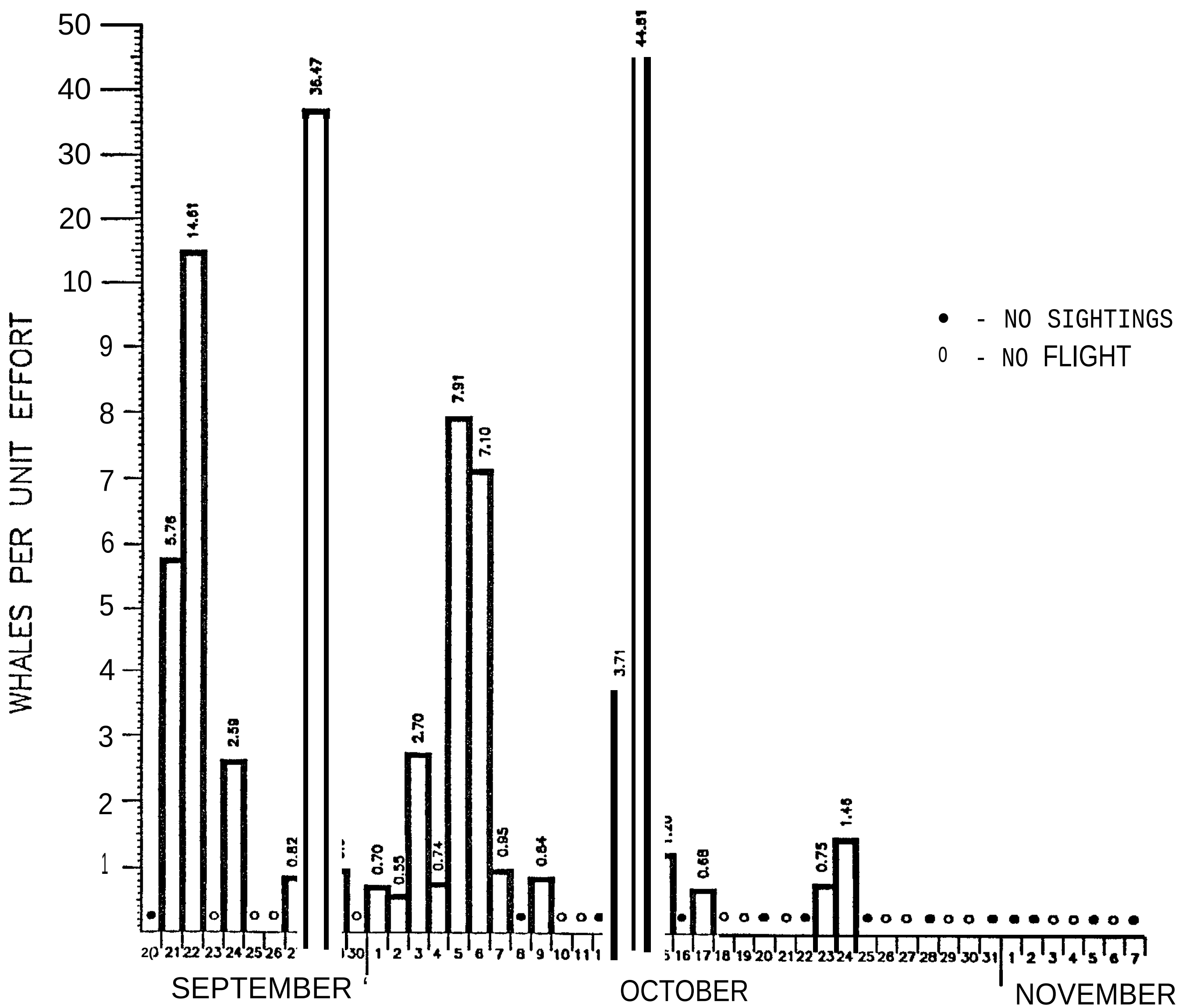


Figure **13. Daily** belukha **WPUE** in **the study area, 1991.**

Table 13. Number and percent of belukhas in each ice cover class, 1991.

Ice Cover (%)	20-30 Sep No.	1"10 Ott No.	11-20 Ott No.	21-31 Ott No.	Total No. (%)
o-1o	13	3	192	14	222 (47%)
11-20	1	1	2	0	4 (l%)
21-30	0	0	8	0	8 (2%)
31-40	96	4	3	0	103 (22%)
41-50	0	1	0	0	1 (<1%)
51-60	4	0	0	0	4 (l%)
61-70	0	22	0	0	22 (5%)
71-80	12	37	0	0	49 (lo%)
81-90	3	7	1	0	11 (2%)
91-99	17	27	7	0	51 (lo%)
Total	146	102	213	14	475

although the correlation between belukha WPUE and ice conditions was not significant ($r= -0.594$, $p<0.41$).

Walrus (Odobenus rosmarus)

There were 245 sightings for a total of 7,573 walruses during the 1991 survey season (Fig. 14). Walruses were strongly associated with the ice edge, the location of which varied during the season (see Fig. 4). High counts of walruses were made on any flight that overflew the ice edge (see Table A-2).

Pinnipeds

There were 21 sightings for a total of 25 bearded seals (Erignathus barbatus) in 1991 (Fig. 15). Most bearded seals were seen near or on ice. As noted below, positively identifying pinnipeds from altitudes greater than about 155 m (500 ft) is generally not possible. There were three sightings of six ringed seals (Phoca hispida); all were seen on the ice in the northern Chukchi Sea in late September (Fig. 15). A comparatively

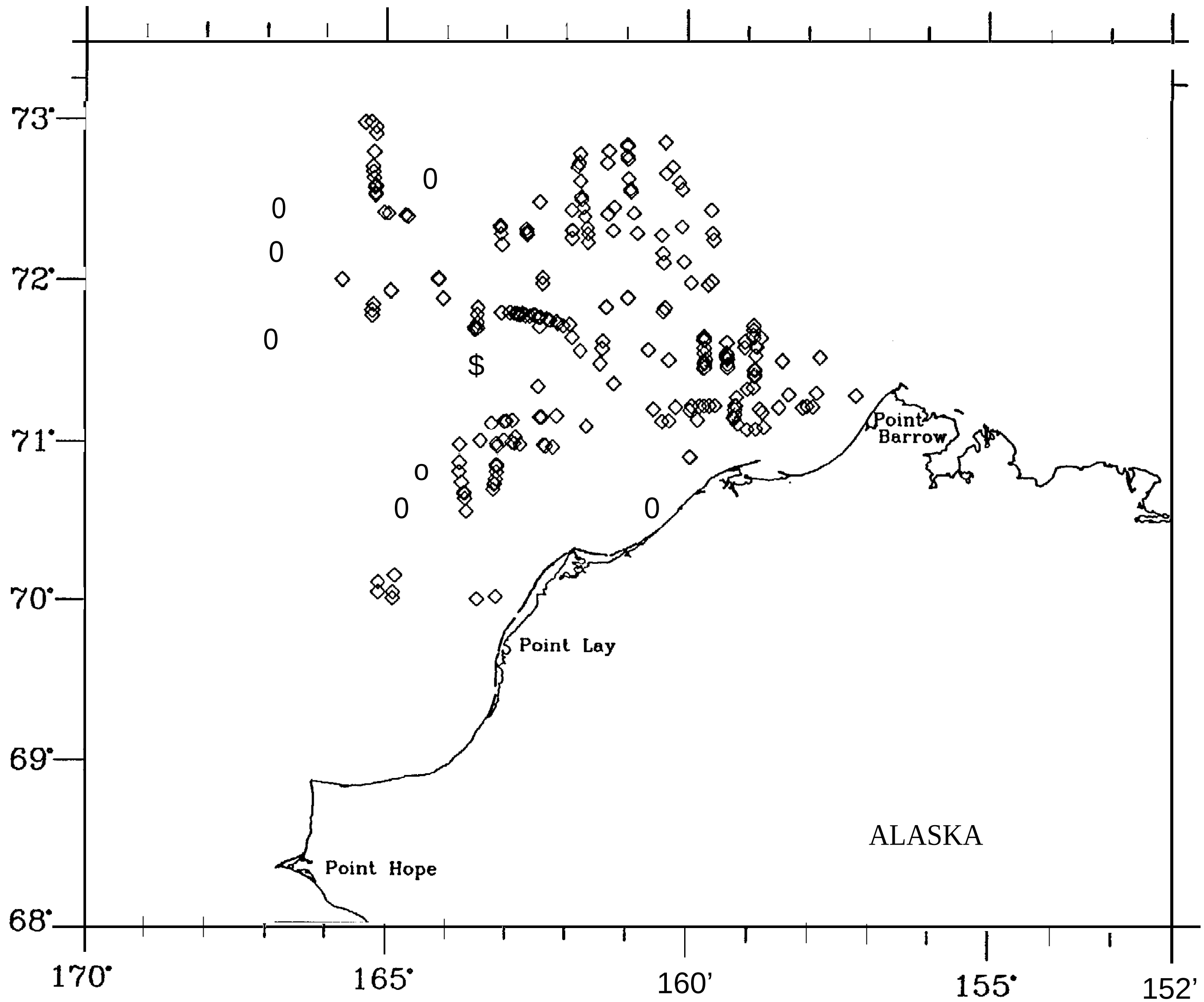


Figure **14.** Distribution **of** 245 **sightings for a total of 7,573 walruses, 1991.**

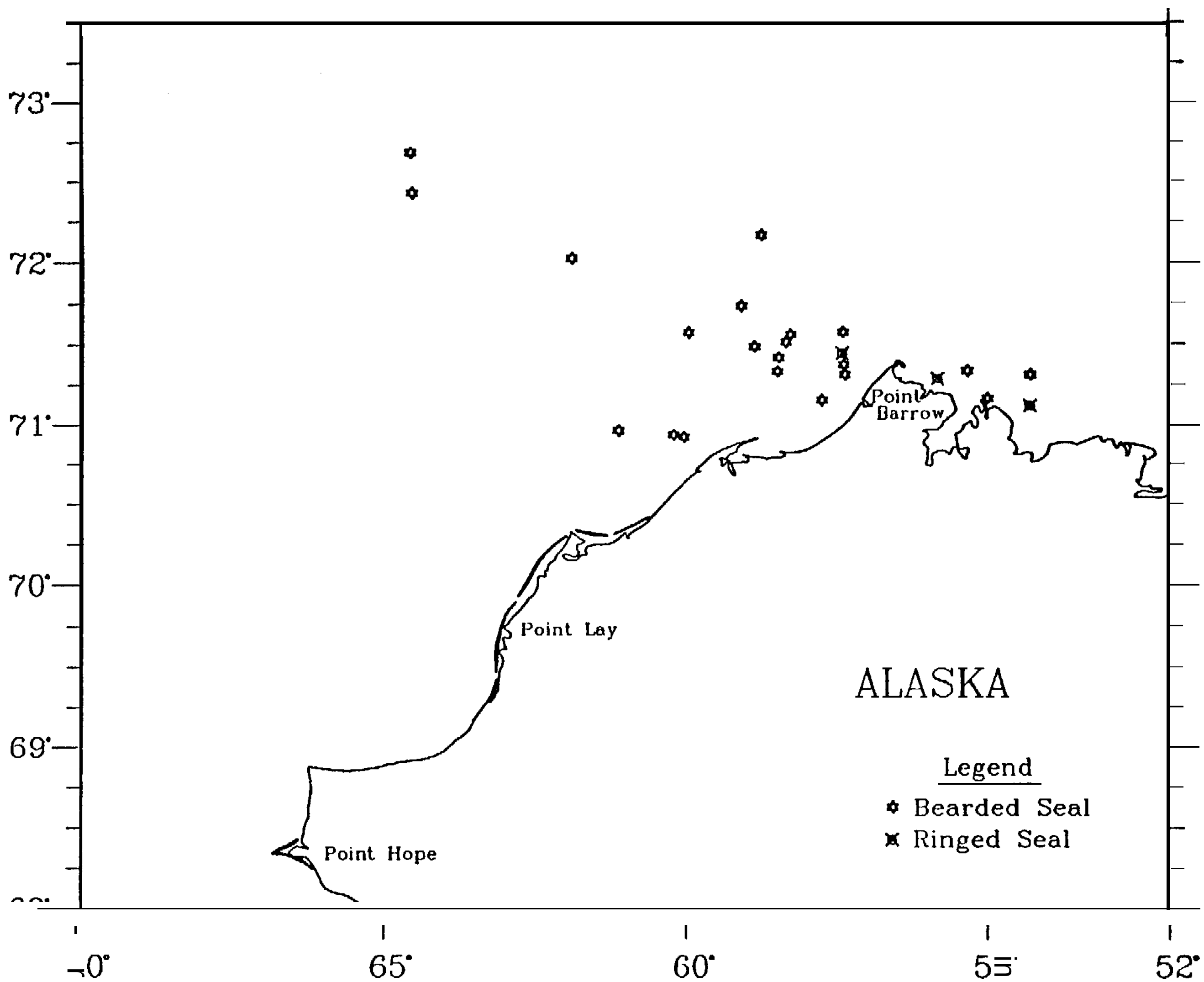


Figure 15. Distribution of 21 sightings for a total of 25 bearded seals and three sightings of six ringed seals, 1991.

uncommon sighting was that of one ribbon seal (Phoca fasciata) seen on 24 September (Appendix A: Flight 4) at 71012.2'N, 161037.1 'W. Male ribbon seals are easily distinguishable from other pinnipeds because of their characteristic pelage. The white bands encircling the neck, shoulders and mid-section were clearly seen from an altitude of 190 m, making it possible to identify the seal as a male. The Alaskan distribution of ribbon seals in fall is not well known, although Kelly (1988) suggests that many migrate into the Chukchi Sea in summer.

Unidentified Pinnipeds

There were 303 sightings for a total of 1,311 unidentified pinnipeds during the survey season (Fig. 16). It is difficult to positively identify pinnipeds when surveying at the target altitude of 458 m (1500 ft.). High counts of unidentified pinnipeds were 102 seen on 1 October (Appendix A: Flight 8) north of icy Cape and 912 recorded on 5 November (Appendix A: Flight 32) hauled out on ice floes in Kotzebue Sound.

Polar Bear (Ursus maritimus)

There were 18 sightings for a total of 28 polar bears during the 1991 season (Fig. 17). Four bears were seen on 24 October (Appendix A: Flight 26), and nine bears were seen on 31 October (Appendix A: Flight 29). The eleven bears seen on 28 and 31 October (Appendix A: Flights 28 and 29) were feeding on a small bowhead carcass frozen into the ice inshore of the barrier islands east of Point Barrow.

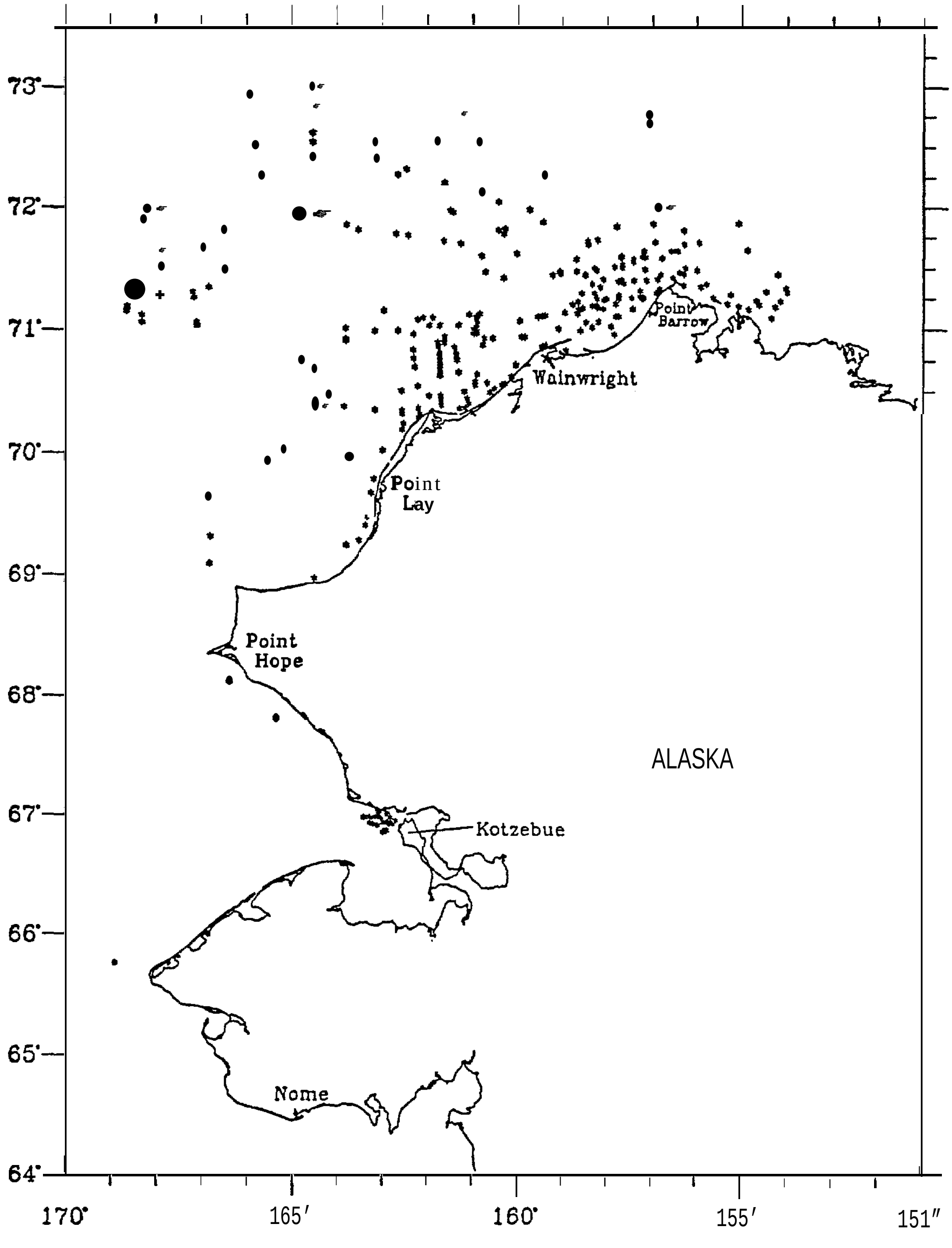


Figure 16. Distribution of 303 sightings for a total of 1,311 unidentified pinnipeds, 1991.

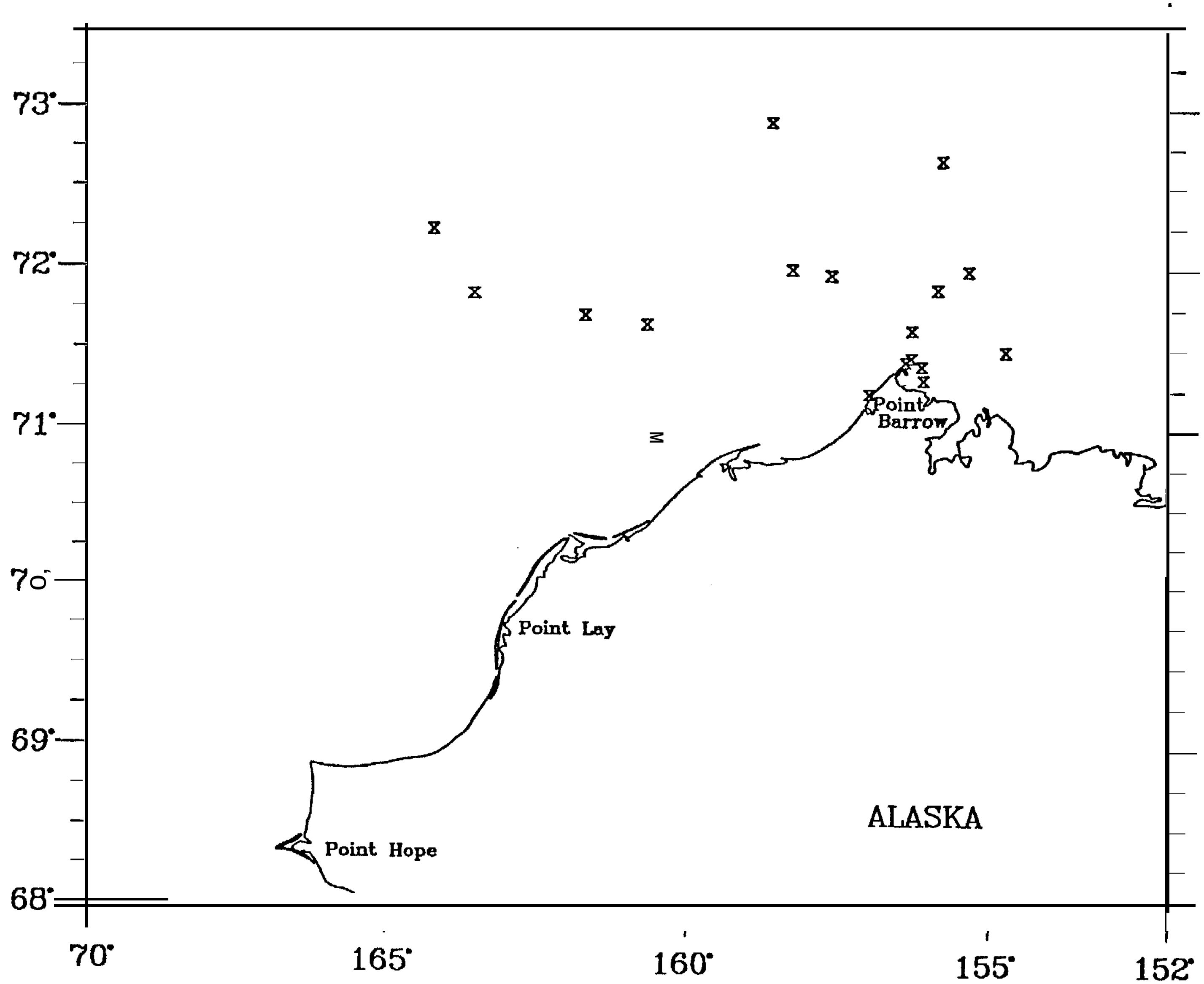


Figure 17. Distribution of 18 sightings for a total of 28 polar bears, 1991.

DISCUSSION AND 1982-91 REVIEW

Survey Effort, Environmental Conditions and Bowhead Sighting Summary

Over 736 survey hours were flown in the study area from mid-September through early November 1982-91, during MMS-funded studies (Table 14). Survey effort varied among years. From 1982-87, effort shifted between the Alaskan Beaufort and Chukchi seas depending on the timing of the bowhead whale migration and ongoing offshore exploration activities. In some years (1982, 1984-85), the priority given the Beaufort Sea resulted in comparatively few survey hours in the Chukchi Sea, while in other years surveys over the Chukchi Sea were less interrupted. In 1988, the survey period was limited to 1-16 October, with effort focused on the northern half of the study area. Surveys were directed solely to the Chukchi Sea study area during 1989-91. However, in 1990, dedicated surveys were restricted to the period 3-11 October and 26 October-7 November, due to the appropriation of the aircraft and crew for search and rescue (SAR) operations (Moore and Clarke 1991).

There were 267 sightings for a total of 552 bowhead whales in the study area from 1982-91 (Table 14). This total includes 5 sightings of 7 bowheads in block 12 on 18 September 1983, two days prior to the beginning of the 1989-91 survey seasons, and excludes 11 sightings of 14 bowheads east of the study area in 1989 (see Moore and Clarke 1990; Treaty 1990). The total also includes five bowheads seen just north of survey block 14N during a SAR flight in 1990 (Moore and Clarke 1991). Bowhead whale numbers and sighting rate were greatest in 1984 and 1989 when aggregations of whales were observed feeding near Point Barrow. Bowhead numbers and sighting rate were relatively low in 1985-87 and 1990-91, although reasons for these low values are unclear.

Over the ten year study period, 1983 was ranked as the year of heaviest ice conditions and 1990 as the year of the lightest ice conditions (Table 14). The ice severity index, used by the U.S. Navy-NOAA Joint Ice Center at the Naval Polar Oceanography Center (NPOC 1992) since 1953, ranks annual ice conditions across the north coast of Alaska between Point Barrow and Prudhoe Bay without regard to conditions in the Alaskan Chukchi Sea. Defining annual ice conditions for the entire study area is

Table 14. Summary of annual survey effort (h), ice index, and bowhead whale sightings (SI), number (No.) and sighting rate (No./h) in the study area, 1982-91. Ice index = relative rank of ice condition severity (1 = lightest; 10 = heaviest) off Alaska's north coast for years 1982-91 (from NPOC 1992).

YEAR	SURVEY EFFORT (h)	ICE INDEX	BOWHEAD WHALES (S1)	(No.)	(No./h)
1982	31.70	4	19	30	0.95
1983	62.13	10	34	50	0.80
1984	38.11	7	45	192	5.04
1985	32.13	6	10	10	0.31
1986	79.18	3	11	15	0.19
1987	87.88	5	24	32	0,36
1988	52.00	9	25	55	1.06
1989	133.87	2	58	117[1]	0,87
1990	85.98[2]	1	14	19[3]	0.22
1991	133.21	8	27	32	0.24
1982-91	736.19		267	552	0.75

1) Excludes 11 sightings of 14 bowheads just east of study area during tracking flights
2) includes 299 h of survey effort north of study area during search and rescue flights
3) Includes 2 sightings of 5 bowheads whales just north of study area during search and rescue flights

problematic given the dynamic nature of the ice edge in the Chukchi Sea during the fall season. An ice-edge frequency map, based on 12 years (1972-83) of satellite imagery (Stringer and Groves 1987), depicts the relative frequency with which oceanic locations were within the ice edge in mid-October (Fig. 18A). The ice edge frequency map smooths out inter-annual variability in ice edge location, such as reported by Muench et al. (1991) for 1987-88 (Fig. 18 B). Intra-seasonal variability caused by storms and high winds further complicates attempts to categorize years by ice conditions in the study area.

Ice conditions observed over the entire study area varied greatly within and among years. To derive an index of observed ice conditions, 'average' ice cover was estimated for each year in the following manner. The amount of random transect survey effort in each ice cover category (0- 10%, 11 -20%, etc.) was tallied, starting with 0-1 O percent, until

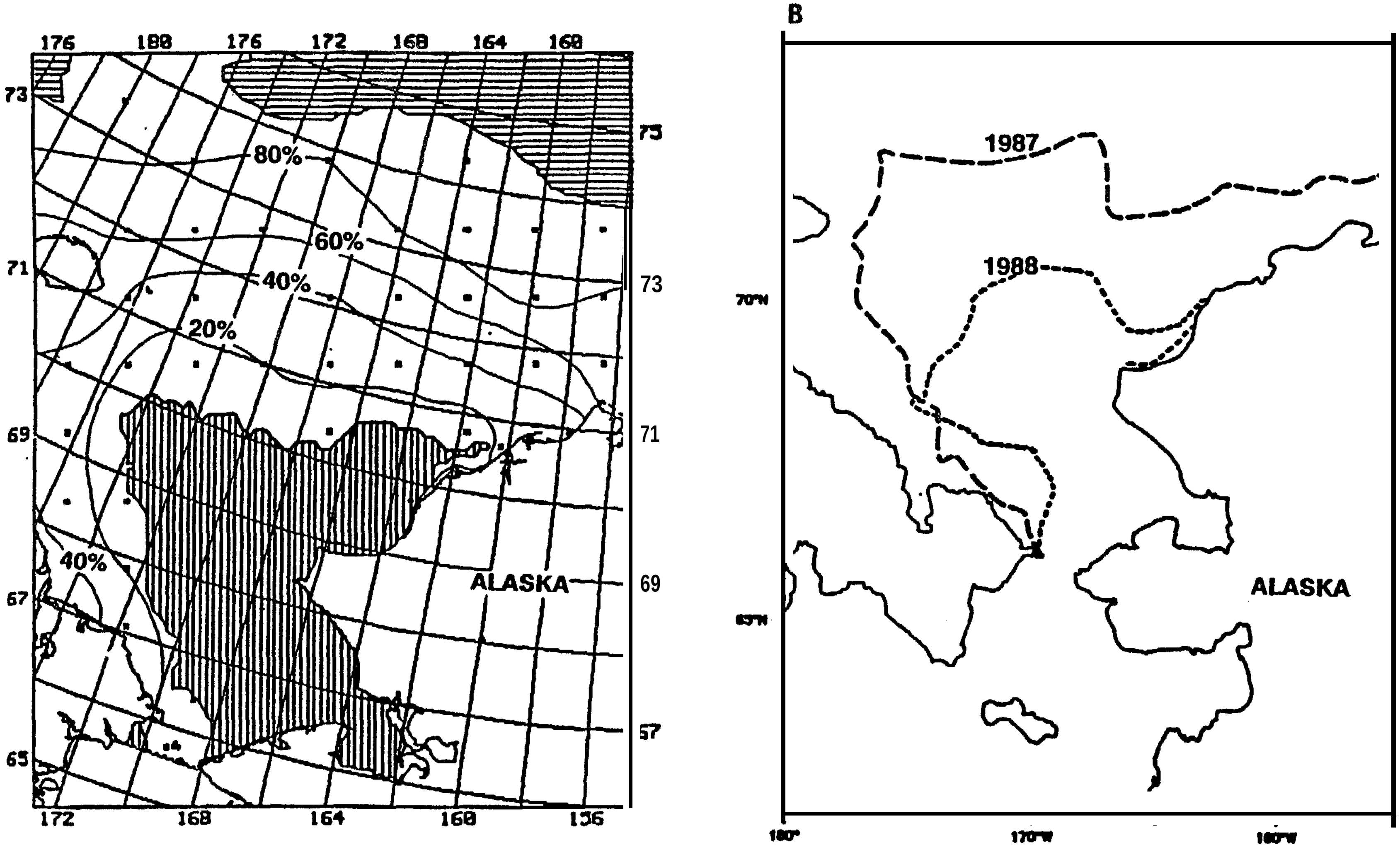


Figure 18. Fall ice cover in the Chukchi Sea: ice edge frequency in mid-October (area with vertical lines was always ice-free; area with horizontal lines always had ice present; from Stringer and Groves 1987) (A) and example of inter-annual variability (from Muench et al. 1991) (B).

≥50 percent of the total transect survey time had been included; the ice cover category in which this occurred was designated the 'average' ice cover for that year. Average ice cover was then indexed to four ice condition categories: no-ice (O-10% ice cover), light-ice (11-40% ice cover), moderate-ice (41-70% ice cover), and heavy-ice (71-100% ice cover). To minimize the effect of inter-annual variability in random transect survey effort over the 10-year period, average ice cover was calculated for the 1" latitudinal band from 71-72" N for the western Beaufort Sea (154-1570 W) and the northeastern Chukchi Sea (157-1690 W). This region roughly corresponds to the marginal ice zone where ice conditions often change dynamically during the fall season.

In the western Beaufort Sea, 1986, 1987, 1989 and 1990 were no-ice years, characterized by little or no ice cover throughout the season, while 1984 was indexed as a light-ice year (Table 15). Heavy-ice years were 1983, 1985, 1988 and 1991. In the northeastern Chukchi Sea, 1984, 1986, 1987, 1989 and 1990 were no-ice years, and 1991 was indexed as a light-ice year. The remaining four years were all heavy-ice years. When total transect time for both areas was added together and indexed to a single ice condition, each year except 1982 was in close agreement with the ice condition index derived for the Beaufort and Chukchi areas. In 1982, most of the flight effort was conducted over predominantly open water in the Beaufort Sea or heavy-ice in the Chukchi Sea.

Results of the observed ice conditions analysis (Table 15) do not completely agree with the U.S. Navy-NOAA Joint Ice Center sea ice severity index for the north coast of Alaska (Table 14; NPOC, 1992). In past reports to MMS (eg., Moore and Clarke 1990), annual ice conditions have been identified as 'light', 'average', or 'heavy', with 1989 and 1990 representing light-ice years and 1983 and 1988 representing heavy-ice years. There was general agreement between the nomenclature used in past reports, the observed conditions, and the Navy-NOAA data regarding the five least severe ice years, 1990, 1989, 1986, 1982 and 1987. However, the observed ice conditions analysis suggested that 1985 was a heavy-ice year, while the Navy-NOAA index ranks 1985 as sixth in ice severity among the ten years, and in past reports 1985 was identified as an average/heavy ice

Table 15. Summary of annual transect survey effort (t-h), ice condition (ICE), bowhead number (No. BH) and sighting rate (BH/h) in the marginal ice zone (71-72" N) in the western Beaufort (154-1570 W) and northeastern Chukchi (157-1690 W) seas.

	W. BEAUFORT				N.E. CHUKCHI SEA				TOTAL			
YEAR	Effort (t-h)	ICE	No. BH	BH/h	Effort (t-h)	ICE	No. BH	BH/h	Effort (t-h)	ICE	No. BH	No./h
1982	7.84	moderate	7	0.89	4.33	heavy	11	2.54	12.17	no-ice	18	1.48
1983	12.12	heavy	12	0.99	9.81	heavy	2	0.20	21.93	heavy	14	0.64
1984	11.40	light	74	6.49	8.27	no-ice	7	0.85	19.67	light	81	4.12
1985	10.54	heavy	4	0.38	2.70	heavy	0	0	13.24	heavy	4	0.30
1986	8.61	no-ice	9	1.05	21.40	no-ice	3	0.14	30.01	no-ice	12	0.40
1987	10.20	no-ice	7	0.69	18.21	no-ice	2	0,11	28.41	no-ice	9	0.32
1988	1.28	heavy	O	0	8.37	heavy	11	1.31	9.65	heavy	11	1.14
1989	2.36	no-ice	4	1.69	13.90	no-ice	8	0.58	16.26	no-ice	12	0.74
1990	2.00	no-ice	6	3.00	5.37	no-ice	1	0.19	7,37	no-ice	7	0.95
1991	9.47	heavy	8	0.84	18,48	moderate	6	0.32	27.96	heavy	14	0.50
Total	75.82	-	131	1.73	110.84	-	51	0.46	186$6		182	0.98

year due to a mid-September storm that dramatically changed ice conditions during the survey season. The observed ice conditions also do not exhibit the 4-6 year cycle for sea ice maximum extent described in Mysak and Manak (1989) from a 32-year multi-source database.

Differences in ice analyses results are probably due to several factors, including the type and frequency of ice data collected and the temporal and spatial parameters used in the analyses. Most ice analyses are based on satellite data (Stringer and Groves 1987), with little or no ground-truthing. While satellite data is an invaluable tool for charting ice movements and predicting shipping-lane passability, it does not detect newly formed grease ice as surely as on-site visual observations. Therefore, it is likely that areas observed and recorded as heavy-ice cover (7 I-1OOYO grease ice) during aerial surveys were not cataloged as such by satellite analysis. Additionally, the Navy-NOAA ice severity ranks do not reflect conditions over the entire Chukchi Sea study area. Finally, Mysak and Manak (1989) report that ice cover in the Beaufort and Chukchi seas is least extensive in August and September, and increases by one-half in October. Therefore, average ice conditions derived during the late fall, as in this study, would be expected to be higher than those derived from data collected from summer or early fall.

Offshore Oil and Gas Exploration

Exploratory drilling was conducted at six sites within the study area during 1989-91. Offshore operations extended from July through October each year, with most activities completed before this study began each fall. Although the surveys described here were not specifically intended to monitor waters near exploratory drilling sites for marine mammals, the study design included an option to break off transect surveys to conduct behavioral observations if bowhead whales were encountered near an active drilling site. Bowheads were never seen near an active drilling site, as detailed in Appendix C. This is likely due to the broad nature of the survey design for this study and its lack of focus on exploratory drilling locations. Bowhead whales and other marine mammals were seen near some of the exploratory drilling sites during site-specific monitoring studies by other researchers, as summarized in Appendix C. The reader is directed to the annual reports of the site-specific studies for bowhead whale and all other marine mammal sighting data collected during these surveys (Brueggeman 1990, 1991, 1992; Gallagher et al. 1992).

Bowhead Whale

Distribution and Relative Abundance

There were 49 sightings for a total of 190 bowhead whales in the study area from 16-30 September, 146 sightings for a total of 265 whales from 1-15 October, 72 sightings for a total of 97 whales from 16-31 October, and 267 sightings for a total of 552 whales overall 1982-91 (Fig. 19). Bowhead distribution was predominantly nearshore between Smith Bay and Point Barrow, and occurred within oil and gas lease area boundaries there

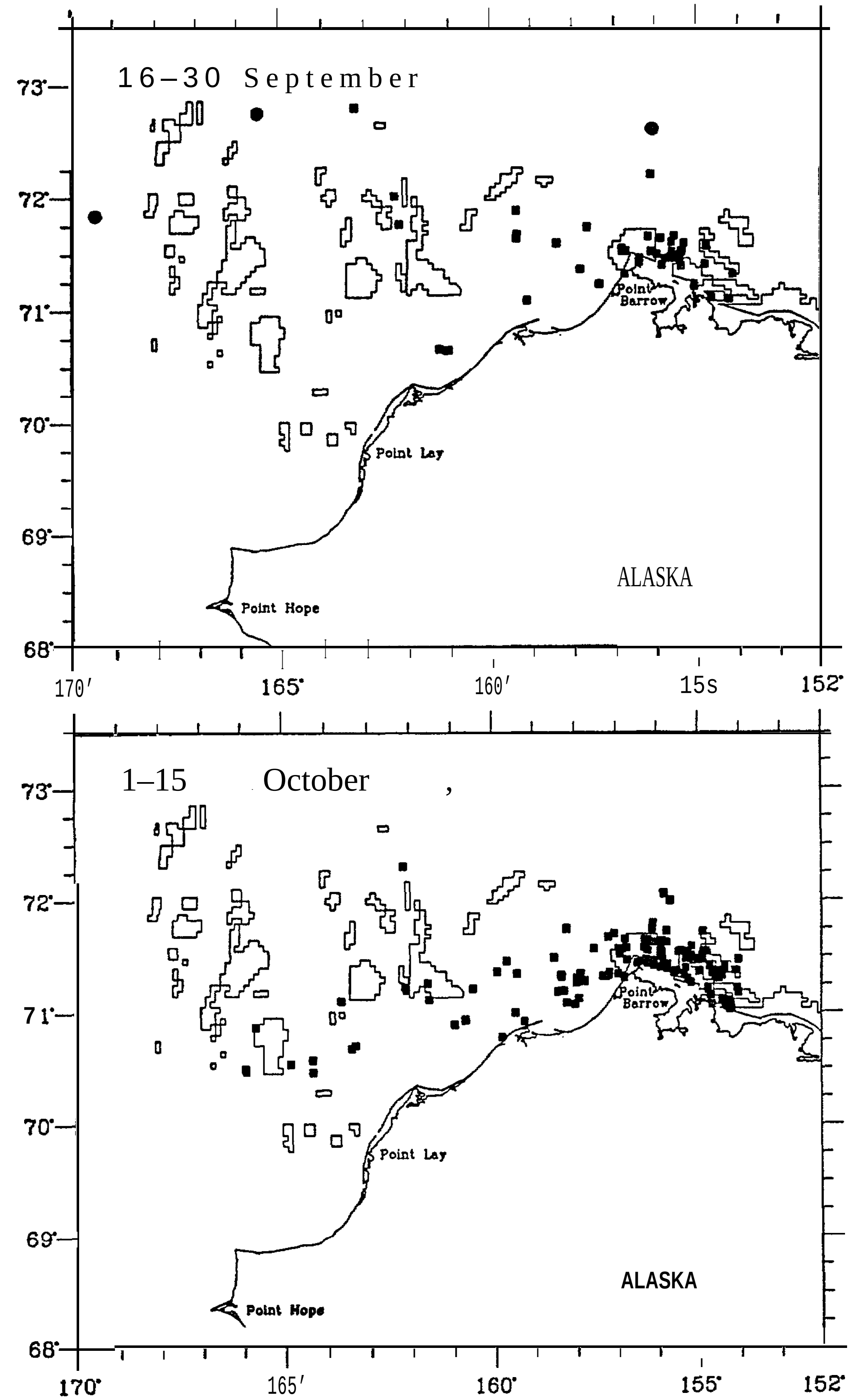


Figure 19. Cumulative (1982-91) bowhead whale distribution relative to OCS lease areas depicting 49 sightings for a total of 190 whales, 16-30 September (● represents USFWS sightings); 146 sightings for a total of 265 whales, 1-15 October;

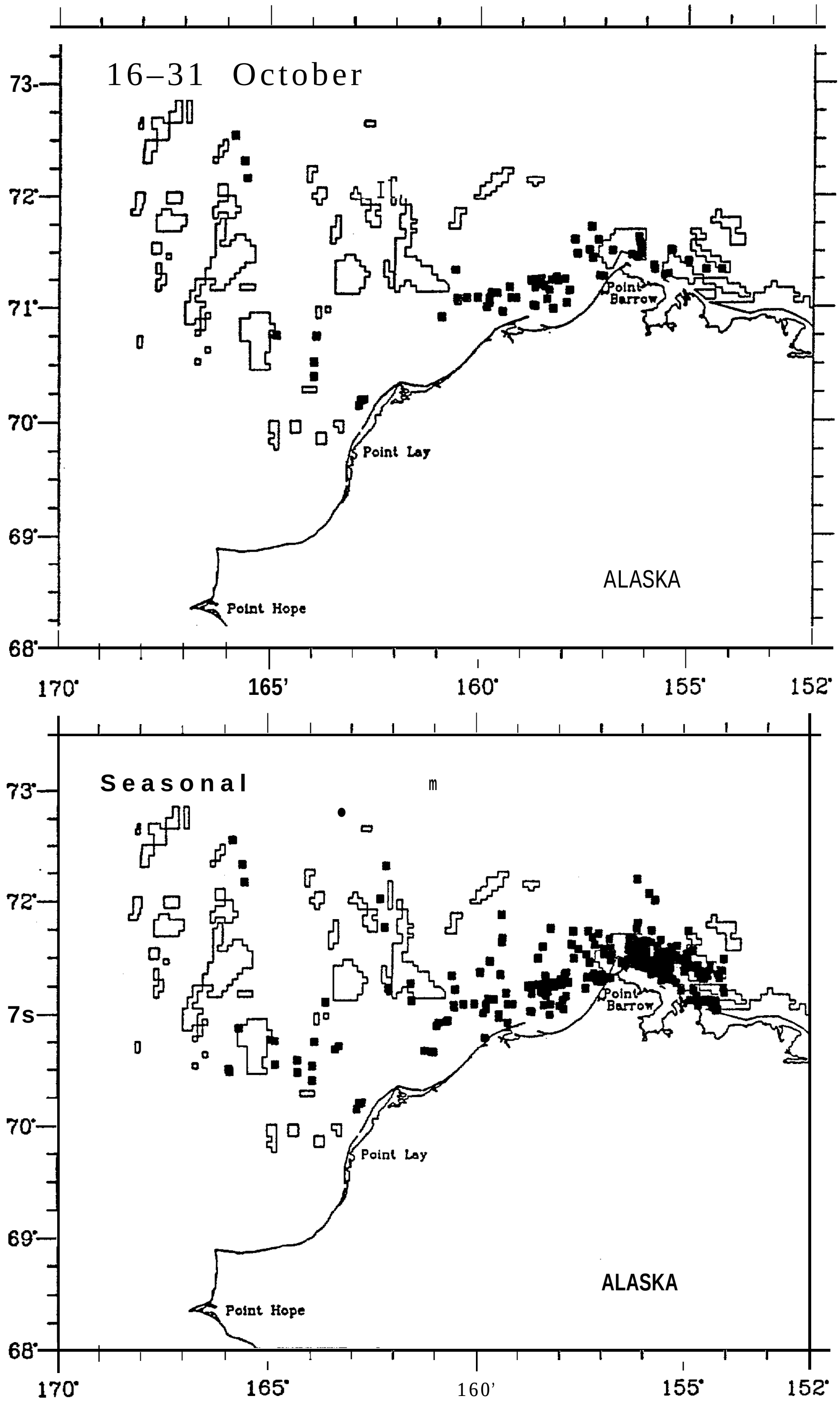


Figure 19 (contd). 72 sightings for a total of 97 whales, 16-31 October; and 267 sightings for a total of 552 whales overall.

during each period. Bowhead distribution in the northeastern Chukchi Sea was predominantly between shore and lease area boundaries south tow. 70” 10’N latitude, with **a few** sightings near or within lease area boundaries in the north-central Alaskan Chukchi Sea.

Bowhead fall distribution in the Alaskan Chukchi Sea is dispersed. Most whales were seen parallel to the coast southwest of Point Barrow to about Point Lay, but some occurred far offshore west and northwest of Point Barrow. This pattern of distribution has been described as ‘bifurcated’ in past reports (eg., Moore and Clarke 1990). While the pattern of distribution southwest of Point Barrow seems obvious, bowhead distribution northwest of the Point is less clear, so ‘bifurcated’ has been dropped in favor of ‘dispersed’ to describe the observed distribution pattern. Although sightings northwest of Point Barrow are few, they occur throughout the fall season. In addition to the sightings during this study, U.S. Fish and Wildlife Service (USFWS) biologists reported seeing three bowhead whales (see ●, Fig. 19) in northern Chukchi waters during surveys flown to assess walrus distribution and numbers in late September 1985. Cumulatively, the bowhead sightings north of 720 N suggest that at least some whales migrate across the northernmost waters of the Alaskan Chukchi Sea throughout the fall season, although the bulk of the population appears to swim southwest from Point Barrow.

Cumulative (1982-91) bowhead whale relative abundance was highest in block 12 (WPUE=2.47), block 13 (WPUE=0.68) and block 18 (WPUE=0.81; Table 16). These comparatively high indices reflect the general pattern of distribution, i.e., most whales occur nearshore north and east of point Barrow and disperse southwest from Point Barrow. Relative abundance indices varied among years. Highest abundance indices were calculated in block 12 in 1984 and 1989, when aggregations of feeding whales occurred there. Conversely, low WPUE values in block 12 were associated with years when little or no feeding behavior was observed there. Relative abundance in block 13 ranged from a low of 0.07 in 1986 to a high of 2.91 in 1988. The, abbreviated survey period in 1988, which targeted the period of peak bowhead migration in the Chukchi Sea, may have influenced the WPUE that year. Abundance indices were relatively high in

Table 16. Bowhead whale relative abundance (WPUE = no. whales/survey hour) by survey block, 1982-91.

1982

Block	16-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	16-31 Ott Hrs	BH	WPUE	1-7 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	4.58	2	0.44	5.85	15	2.56	2.18	0	0	0.00	·	·	12.61	17	1.35
12N	0.00	-	-	0.07	0	0	0.07	0	0	0.00	-		0.14	0	-
13	1.48	0	O	3.58	12	3.35	0.76	0	0	0.00	·	·	5.82	12	2.06
14	0.00	-	-	1.93	0	0	0.48	1	2.08	0.00	·	·	2.41	1	0.41
15	0.00	-	-	0.12	0	0	0.00	-	-	0.00	·	·	0.12	0	0
17	0.00	-	-	3.86	0	0	0.00	-	-	0.00	·	·	3.86	0	0
18	0.00	-	-	1.97	0	0	0.00	-	-	0.00	·	·	1.97	0	0
20	0.00	"	-	3.42	0	0	0.00	-	-	0.00	·	·	3.42	0	0
21	0.00	-	-	1.35	0	0	0.00	-	-	0.00	·	·	1.35	0	0
Total	6.06	2	0.33	22.15	27	1.22	3.49	1	0.29	0.00	-		31.70	30	0,95

1983

Block	18-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	16-31 Ott Hrs	BH	WPUE	1-7 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	7.89	18	2.28	8.23	8	0.97	2.45	0	0	0.00			18.57	26	1.40
12N	0.26	0	0	0.61	0	0	0.11	0	0	0.00	·		0.99	0	0
13	3.29	3	0.91	5.14	4	0.78	3.74	9	2.41	0.00		·	12.17	16	1.32
13N	0.00	-	-	0.24	0	0	0.09	0	0	0.00			0.33	0	0
14	0.87	0	0	2.07	0	0	1.90	0	0	0.00		·	4.84	0	0
15	0.00	-	-	3.28	0	0	0.39	0	0	0.00	·	-	3.67	0	0
15N	0.00	-	-	0.56	0	0	0.00	·	-	0.00		·	0.56	0	0
17	0.96	3	3.13	3.85	3	0.78	0.47	0	0	0.00			5.28	6	1.14
18	0.00	-	-	1.51	0	0	3.08	2	0.65	0.00		-	4.59	2	0.43
19	0.00	-	-	0.32	0	0	0.04	0	0	0.00			0.36	0	0
20	0.00	-	-	0.76	0	0	2.23	0	0	0.00		-	2.99	0	0
21	0.00	-	-	0.36	0	0	1.36	0	0	0.00			1.73	0	0
22	0.00	-	-	3.22	0	0	0.38	0	0	0.00			3.60	0	0
23	0.00	-	-	0.23	0	0	0.36	0	0	0.00			0.59	0	0
24	0.00	-	-	0.00	-		0.34	0	0	0.00			0.34	0	0
25	0.00	-	-	0.00			0.51	0	0	0.00	-		0.51	0	0
28	0.00	-	-	0,00			0.18	0	0	0.00		-	0.18	0	0
30	0.00	-	-	0.85	0	0	0.00		-	0.00	·	·	0.85	0	0
Total	13.27	24	1.81	31.23	15	0.48	17.63	11	0.62	0.00			62.13	50	0.80

1984

Block	18-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	16-31 Ott Hrs	BH	WPUE	1-7 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	5.64	148	26.24	7.63	25	3.28	7.97	12	1.51	0.00		·	21.24	185	8.71
12N	0.09	0	0	0.30	0	0	0.12	0	0	0.00			0.51	0	0
13	4.77	2	0.42	3.14	3	0.96	2.63	2	0.76	0.00		·	10.54	7	0.66
13N	0.02	0	0	0.03	0	0	0.20	0	0	0.00	·	·	0.25	0	0
14	2.79	0	0	0,11	0	0	0.00	"	-	0.00	·	·	2.90	0	0
14N	0.02	0	0	0.00	-		0.00	-	-	0.00			0.02	0	0
17	0.75	0	0	1.90	0	0	0.00	-	-	0.00		-	2.65	0	0
Total	14.08	150	10.65	13.11	28	2.13	10.92	14	1.28	0.00	-		38.11	192	5.04

Table 16 (contd).

1985

Block	16-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	16-31 Ott Hrs	BH	WPUE	1-7 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	3.09	0	0	6.08	6	0.99	7.18	1	0.14	0.00	-	-	16.35	7	0.43
12N	0.06	0	0	0.63	0	0	0.02	-	-	0.00	-	·	0.71	0	0
13	0.00	-	-	2.79	2	0.72	3.62	0	0	0.00	-		6.41	2	0.31
14	0.00	-	-	2.04	1	0.49	0.00	-	-	0.00	-	·	2.04	1	0.49
?5	0.00	-	-	1.03	0	0	0.00	-	-	0.00	-	·	1.03	0	0
17	0.00	-	-	2.59	0	0	0.00	-	-	0.00	-	·	2.59	0	0
18	0.00	-	-	2.90	0	0	0.00	-	-	0.00	-	·	2.90	0	0
20	0.00	-	-	0.10	0	0	0.00	-	-	0.00	-	·	0.10	0	0
Total	3.15	0	0	18.16	9	0.50	10.82	1	0.09	0.00	-	-	32.13	10	0.31

1986

Block	16-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	16-31 Ott Hrs	BH	WPUE	1-7 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	3.33	0	0	8.34	11	1.32	3.78	0	0	0.00	-	-	15.45	11	0.71
12N	0.10	0	0	1.33	0	0	0.11	0	0	0.00	-		1,54	0	0
13	11.15	0	0	9.11	0	0	6.60	2	0.30	0.00	-	-	26.86	2	0.07
13N	0.52	0	0	1.80	0	0	0.00			0.00	-		2.32	0	0
14	4,50	1	0.22	7.31	1	0.14	0.62	0	0	0.00	-	-	12.44	2	0.16
14N	0.06	0	0	0.15	0	0	0.00			0.00	-		0.21	0	0
15	2.74	0	0	0.20	0	0	0.19	0	0	0.00	-	·	3.13	0	0
17	3.75	0	0	3.92	0	0	3.42	0	0	0.00	-	-	11.09	0	0
18	1.01	0	0	2.17	0	0	0.53	0	0	0.00	-	·	3.71	0	0
20	1.59	0	0	0.00	-	-	0.05	0	0	0.00	-		1.64	0	0
22	0.80	0	0	0.00	-	-	0.00			0.00	-		0.80	0	0
Total	29.55	1	0.03	34.33	12	0.35	15.30	2	0.13	0.00	-	-	79.18	15	0.19

1987

Block	16-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	18-31 Ott Hrs	BH	WPUE	1-7 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	7.72	2	0.26	7.11	21	2.95	8.11	5	0.62	0.00	-	-	22.94	28	1.22
12N	2.74	1	0.36	3.35	0	0	4.14	0	0	0.00	-	-	10.23	1	0.10
13	10.96	1	0.09	8.04	0	0	4.85	2	0.41	0.00	-	-	23,85	3	0.13
13N	1.73	0	0	1.09	0	0	2.38	0	0	0.00	-		5.20	0	0
14	5.31	0	0	2.62	0	0	0,03	-	-	0.00	-		7.96	0	0
15	3.44	0	0	0.00	-	-	0.00	-	-	0.00	-		3.44	0	0
16	0.41	0	0	0.00	-	-	0.00	-	-	0.00	-	·	0.41	0	0
17	2.60	0	0	0,95	-	-	2.88	0	0	0.00	-	·	6.43	0	0
18	2.86	0	0	0.00	-	-	0.54	0	0	0.00	-	·	3.40	0	0
20	1.68	0	0	0,00	-	-	0.00	-	-	0.00	-	·	1.68	0	0
22	2,34	0	0	0.00	-	-	0.00	-	-	0.00	-	·	2.34	0	0
Total	41.79	4	0.10	23.16	21	0.91	22.93	7	0.31	0.00	-	-	87.88	32	0.36

Table 16 (contd).

	1988														
	16-30 Sept			1-15 Ott			16-31 Ott			1-7 Nov			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
?2	0.00	-	-	2.79	3	1.08	0.19	o	o	0.00		-	2.98	3	1.01
12N	0.00	-	-	3.06	0	0	0.00	·	-	0.00	-	-	3.06	0	0
13	0.00	-	-	8.86	29	3.27	1.12	0	0	0.00	-	-	9.98	29	2.91
13N	0.00	-	-	3.58	0	0	0.00	0	0	0.00	·	-	3.58	0	0
14	0.00	-	-	5.11	7	1.37	0.16	0	0	0.00	·	-	5.27	7	1.33
14N	0.00	-	-	2.76	0	0	0.00	·	"	0.00	·	-	2.76	0	0
15	0.00	-	-	3.67	0	0	0.00	·	-	0.00	·	-	3.67	0	0
15N	0.00	-	-	3.62	0	0	0.00	·	-	0.00		-	3.62	0	0
16	0.00	-	-	3.21	0	0	0.00	·	-	0.00		-	3.21	0	0
16N	0.00	-	-	3.89	0	0	0.00	·	-	0.00	·	-	3.89	0	0
?7	0.00	-	-	2.41	0	0	1.36	0	0	0,00		-	3,77	0	0
18	0.00	-	-	4.13	14	3.39	1.18	2	1.69	0.00	-	-	5.31	16	3.01
19	0.00	-	-	0.86	0	0	0.00	·	"	0.00	·	"	0.86	0	0
20	0.00	-	-	0.04	0	0	0.00	·	-	0.00	·	-	0.04	0	0
Total	0.00	-	-	47.99	53	1.10	4.01	2	0.50	0.00	·	-	52,00	55	1.06

	1989														
	16-30 Sept			1-15 Ott			16-31 Ott			1-7 Nov			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
12	5.47	4	0.73	4.29	66	15.38	1.18	5	4.24	0.00	-	-	10.94	75	6.88
12N	4.70	0	0	0.00	·	-	0.00	-	·	0.00	-	-	4.70	0	0
13	7.82	0	0	6.51	0	0	12.88	21	1.63	0.00	-	-	27,21	21	0.77
13N	3.44	0	0	0.92	0	0	3.23	0	0	0.00	-	-.	7.59	0	0
14	3.18	o	0	6.86	0	0	4.39	4	0.91	0.00		-	14.43	4	0.28
14N	3.73	1	0.27	3.39	1	0.29	0.41	0	0	0.00		-	7.54	2	0.27
?5	2.12	0	0	2.20	0	0	4,03	0	0	0.00		-	8.35	0	0
15N	3.91	1	0.26	2.98	0	0	3.74	1	0.27	0.00	-	-	10.63	2	0.19
16	0.39	0	0	0,00		-	3.40	0	0	0.00		"	3.79	0	0
16N	3.01	0	0	0,00	·		0.05	0	0	0.00		-	3.06	0	0
17	0.00		-	3.06	0	0	2.79	1	0.36	0.00		-	5.85	1	0.17
18	0.68	0	0	0.02			5.85	12	2,05	0.00		-	6.55	12	1.83
20	0.00	·	-	0.00			2.30	0	0	0.00		-	2.30	0	0
21	0.00	·	-	0.00	·	-	0.24	0	0	0.00	-	-	0.24	0	0
22	0.00	·	-	0.00	·		4.83	0	0	0.00	-	-	4.83	0	0
23	0.00	·	-	0.00		-	2.50	0	0	1.11	0	0	3.61	0	0
24	0.00	·	-	0.00	·		0.00	·	-	4.04	0	0	4.04	0	0
25	0.00	·	-	0.00	·		0.00	·	·	1.32	0	0	1.32	0	0
30	0.00	-	-	0.00	·	-	1.97	0	0	0.77	0	0	2.74	0	0
31	0.00		-	0.00	-	-	0.47	0	0	3.68	0	0	4.15	0	0
Total	38.46	6	0.16	30.23	67	2.22	54.26	44	0.81	10.92	0	0	133.87	117	0.87

Table 16 (contd). ['whales seen just north of study area]

1990

Block	16-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	16-31 Ott Hrs	BH	WPUE	1-7 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	0.00	-	-	7.08	7	0.99	2.32	0	0	1.09	0	0	10.49	7	0.67
12N	0.00			1.33	0	0	2.69	0	0	2.80	0	0	6.82	0	0
13	0.00	·	-	2,11	2	0.95	3.83	3	0.78	2.37	0	0	8.31	5	0.60
13N	0.00	·	-	0.94	0	0	3.31	0	0	1.14	0	0	5.39	0	0
14	0.00	-	-	0.00	·	-	3.14	0	0	0.64	0	0	3.78	0	0
14N	0.00	·	-	3.40	5*	1,47	2.29	0	0	1.00	0	0	6.69	5	0.75
15	0.00		-	0.00			1.80	0	0	0.19	0	0	1.99	0	0
15N	0.00	·	-	0.00	·	-	2.60	2	0.77	0.00	-	-	2.60	2	0.77
16	0.00	-	-	0.00	·	-	0.15	0	0	0.00	-	-	0.15	0	0
16N	0.00	·	-	0.00	·	-	0.20	0	0	0.00		-	0.20	0	0
18	0.00	·	-	0.00	·	-	0.02	0	0	0.56	0	0	0.58	0	0
20	0.00	·	-	0.00	-	-	0.00			0.15	0	0	0.15	0	0
21	0.00	·	-	0.00		-	0.00			0,70	0	0	0.70	0	0
22	0.00	·	-	0.00	·	-	0.00	·		0.80	0	0	0.80	0	0
23	0.00		-	0.00	·	-	0.00	-		1,12	0	0	1.12	0	0
24	0.00		-	0.00		-	0.00	-		0.13	0	0	0.13	0	0
30	0.00	·	-	0.00	·	-	0.00			3.87	0	0	3.87	0	0
31	0.00	·		0.00	·	-	0.00			2.31	0	0	2.31	0	0
Total	0.00	·	-	14.86	14	0.94	22.35	5	0.22	18.87	0	0	56.08	19	0.34

1991

Block	16-30 Sept Hrs	BH	WPUE	1-15 Ott Hrs	BH	WPUE	16-31 Ott Hrs	BH	WPUE	1-7 Nov Hrs	BH	WPUE	Total Hrs	BH	WPUE
12	5.82	0	0	8.07	14	1.73	5.36	0	0	0.00		-	19.25	14	0.73
12N	1.61	0	0	2.52	2	0.79	5.00	0	0	0.00		-	9.13	2	0.22
13	7.26	3	0.41	11.70	2	0.17	9.23	6	0.65	0.36	0	0	28.55	11	0.39
13N	3,13	0	0	5.30	0	0	0.29	0	0	0.00		-	8.72	0	0
14	1.96	0	0	5.97	0	0	4.03	0	0	0.09	0	0	12.05	0	0
14N	1.83	0	0	4.87	0	0	0.11	0	0	0.00		-	6.81	0	0
15	0.00		-	4.83	1	0.21	1.07	0	0	0.00		-	5.90	1	0.17
15N	0.00	·	-	1.90	0	0	2.61	0	0	0.00		-	4.51	0	0
16	0.00	·	-	0.17	0	0	2.93	0	0	0.00		-	3.10	0	0
16N	0.00	·	-	3.10	0	0	0.16	0	0	0.00		-	3.26	0	0
17	0.00		-	2.96	0	0	3.46	4	1.16	0.27	0	0	6.69	4	0.60
18	0.00		-	5.23	0	0	2.65	0	0	0.38	0	0	8.26	0	0
19	0.00		-	0.00		·	1.51	0	0	0.72	0	0	2.23	0	0
20	0.00	-	-	0.07	0	0	2.93	0	0	0.00	0	0	3.00	0	0
21	0.00	·	-	0.00	·	-	0.00			1.38	0	0	1.38	0	0
22	0.56	0	0	0.00	-	-	0.00			0.77	0	0	1,33	0	0
23	0.00		-	0.00	-	-	0.00			0.48	0	0	0.48	0	0
24	0.00		-	0.00		-	0.00			0.87	0	0	0.87	0	0
25	0.00		-	0.00		-	0.00			0.67	0	0	0.67	0	0
30	0.87	0	0	0.00		-	0.00		-	3.57	0	0	4.44	0	0
31	0.00	·	-	0.00		-	0.00	-		2.58	0	0	2.58	0	0
Total	23.04	3	0.13	56.69	19	0.34	41.34	10	0,24	12.14	0	0	133.21	32	0.24

Table 16 (contd).

CUMULATIVE 1982-91

	16-30 Sept			1-15 Ott			18-31 Oct			1-7 Nov			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
12	43.54	174	4.00	65.47	176	2.69	40.71	23	0.56	1.10	o	0	150.82	373	2.47
12N	9.57	1	0.10	13.22	2	0.15	12.27	0	0	2.80	0	0	37.86	3	0.08
13	46.73	9	0.19	60.97	54	0.89	49.26	45	0.91	2.73	0	0	159.69	108	0.68
13N	8,85	0	0	13.91	0	0	9.50	0	0	1.14	0	0	33.40	0	0
14	18.62	1	0.05	34.03	9	0.26	14,74	5	0.34	0.73	0	0	68.12	15	0.22
14N	5.67	1	0.18	14.61	6	0.41	2.82	0	0	1.00	0	0	24.10	7	0.29
15	8.30	0	0	15.34	1	0.07	7,48	0	0	0.19	0	0	31.31	1	0.03
15N	3.98	t	0.25	9.06	0	0	8.95	3	0.34	0.00			21.99	4	0.18
16	0.79	o	0	3.38	0	0	6.47	0	0	0.00	·		10.64	0	0
16N	3.01	0	0	6.99	0	0	0.41	0	0	0.00			10.41	0	0
17	8.05	3	0.37	25.50	3	0.11	14.38	5	0.35	0.27	0	0	48.20	11	0.23
18	4.56	0	0	17.92	14	0.78	13,83	16	1.16	0.94	0	0	37,25	30	0.81
19	0.00	·	·	1.19	0	0	1.54	0	0	0.72	0	0	3.45	0	0
20	3.27	0	0	4.40	0	0	7.50	0	0	0.15	0	0	15.32	0	0
21	0.00	·	·	1.71	0	0	1.60	0	0	2.08	0	0	5.39	0	0
22	3.70	0	0	3.22	0	0	5.21	0	0	1.56	0	0	13.69	0	0
23	0.00		-	0.23	0	0	2.86	0	0	2.70	0	0	5.79	0	0
24	0.00	·	·	0.00			0.34	0	0	5.03	0	0	5.37	0	0
25	0.00	·	·	0.00	·	-	0.51	0	0	1.99	0	0	2.50	0	0
28	0.00	-		0.00	·	·	0.18	0	0	0.16	0	0	0.34	0	0
30	0.87	0	0	0.85	·	·	1.97	0	0	8.20	0	0	11,89	0	0
31	0.00	·	·	0.00	·		0.47	0	0	8.56	0	0	9.03	0	0
Total	169.51	190	1.12	292.00	265	0.91	203.00	97	0.48	42.05	0	0	706.56	552	0.78

block 18 in 1988 (WPUE=3.01) and 1989 (WPUE= 1.83), with no whales seen there in any other year except 1983 (WPUE=0.43).

Abundance indices did not appear to be directly related to ice cover. When ice conditions were ranked as no-ice= 1, light-ice =2, moderate-ice =3 and heavy-ice =4 (see Table 15), there was no correlation between annual relative abundance (BH/h) and ice condition rank in the western Beaufort Sea ($r= -0.372$, $p< 0.20$), the northeastern Chukchi Sea ($r= 0.389$, $p <0.20$), or over the entire marginal ice zone ($r= 0.124$, $p <0.50$). In the western Beaufort Sea, there were more bowhead whales observed in light-ice years than expected (log-likelihood G= 120.24, $p< 0.001$). This was likely due to the aggregations of feeding whales seen east of Point Barrow during transect surveys in 1984; feeding whales observed there in 1989 were seen during search surveys and did not factor in this this analysis. Conversely, in the northeastern Chukchi Sea, more bowhead whales were seen in heavy-ice years than expected (log-likelihood G =13.45, $p< 0.001$). The lack of correlation between annual sighting rate and observed ice condition, and the diametric inference implied by the log-likelihood results for the two seas, suggest that the relationship between ice cover and observed bowhead relative abundance is not a simple one. indeed, bowhead relative abundance seems directly influenced more by feeding opportunities than any other single factor (see block 12, Table 16, 1984 and 1989 vs. other years).

Migration Timing and Axis

The timing of the bowhead migration into the Chukchi Sea can be inferred from cumulative (1982-91) random sighting (rSI) sighting rate (SR = rSI/transect hour) for the western Beaufort Sea (survey blocks 12 and 12N) by calendar date (Fig. 20). Whales were seen in this area from 18 September through 23 October, in a temporal pattern significantly different (log-likelihood G =296.80, p c 0.001) from uniform. However, distinct migration pulses were not clearly evident from the SR histogram. Sighting rate was relatively high on 18 and 22 September, feli to zero on 29 September, then steadily increased to peaks on 11 October (SR = 3.30) and 15 October (SR = 3.68), falling to SR =0.36 on 23 October. The 22 September SR was strongly influenced by the sighting'

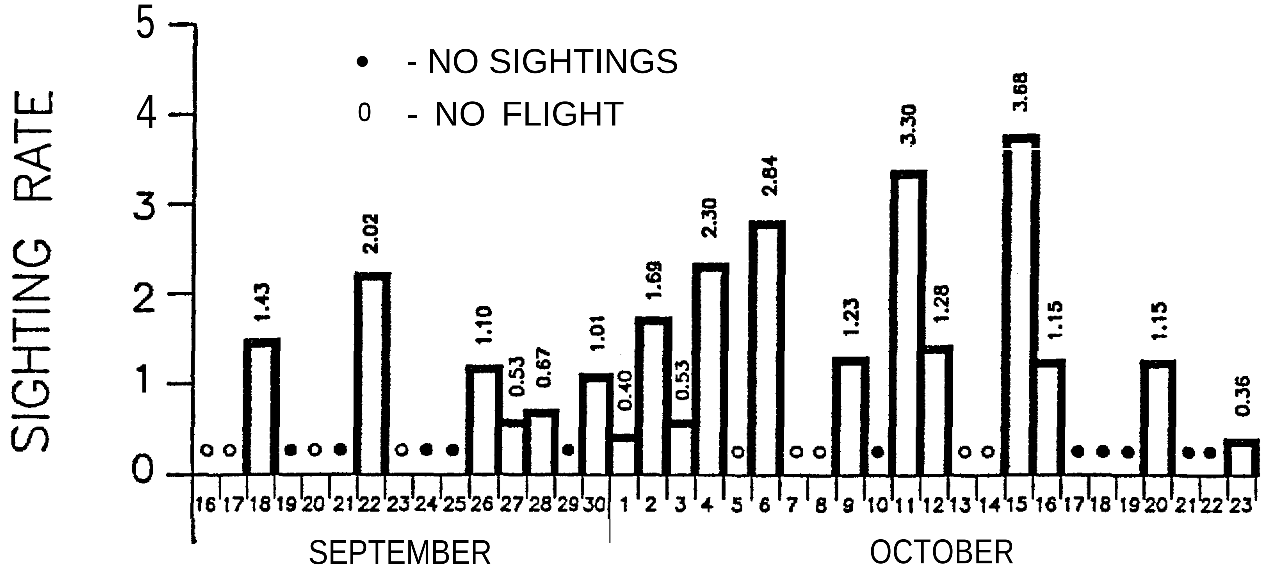


Figure 20. Bowhead whale migration timing into the Chukchi Sea as indicated by random sighting (rSI) sighting rate (SR = rSI/t-h) in the western Beaufort Sea (survey blocks 12 and 12N), 1982-91.

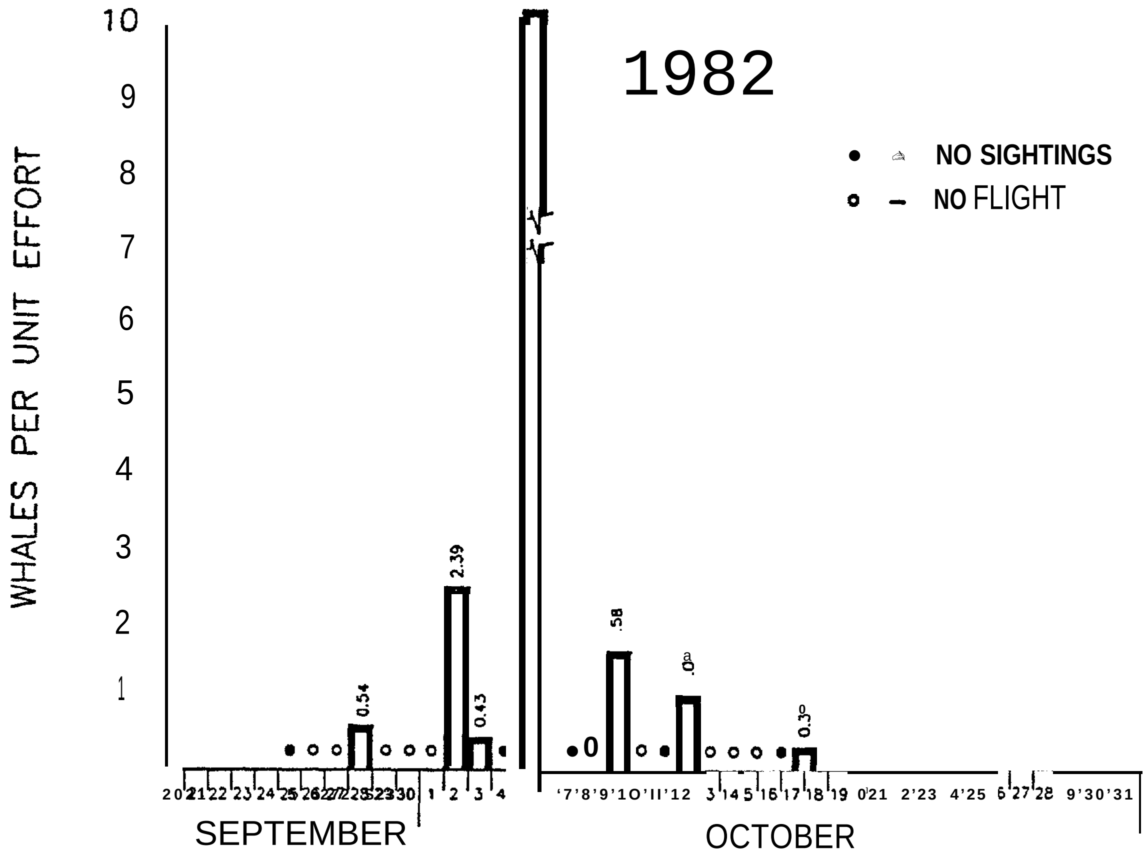
of 49 feeding bowheads in block 12 in 1984. The overall SR pattern, although not strongly suggestive of migration pulses, indicates that bowheads enter the Chukchi Sea at least by late September, with the bulk of the population reaching the Chukchi Sea in October.

It is important to emphasize that these data represent migration timing only for mid-September through October. Bowhead whales were seen as far west as 71023.5'N, 161°04.8'W on 24 August 1991 (Appendix C), and within about 37 km (20 nmi) of Point Barrow as early as 23 July 1989 (Moore and Clarke 1990). These sightings, and others reported since the late 1970's, suggest that some bowheads summer in, or migrate to, the Chukchi Sea prior to late September (Moore 1992). Sighting rate and swimming direction analysis for bowheads seen in the eastern Alaskan Beaufort Sea from 1979-86 suggest that some whales may begin migrating westward in August, although swimming direction was not significantly clustered about a westerly direction until September (Moore et al. 1989b). Whales swimming at an average speed of 4 km/h could migrate from the U.S./Canadian border to Point Barrow (ca. 600 km) in about a week (Wartzok et al.

1990). Thus, it is possible that whales seen near Barrow in late summer represent 'early' fall migrants from the central Beaufort Sea. In summary, the absolute period that bowheads occur in the Chukchi Sea likely varies annually and cannot be fully described from a database that extends only from mid-September through October.

The temporal occurrence of bowhead whales in the overall study area, as represented by daily WPUE (Fig. 21), was relatively consistent among years. Over ten years (1982-91), bowheads were seen from 18 September (1983) through 31 October (1991), with 9-10 day intervals between sighting rate peaks. The seasonal peak sighting date occurred between 4-6 October in six of ten years (1982, 1983, 1985, 1987, 1989 and 1991). Daily WPUE rates in 1984 were highest in late September, as a result of bowhead feeding aggregations seen east of Point Barrow, with a second cluster of high sighting rates between 11 and 20 October. Comparatively high WPUE rates were also recorded in mid-October in 1988 and 1989, but not in other years. The aforementioned variability in annual survey effort likely affected WPUE rates. For example, the survey season ended by 24 October in 1982-87. In 1988, surveys were flown only from 1-16 October, and in 1990 surveys were intermittent throughout October, with no effort in September. Surveys were flown from 20 September through early November in 1989 and 1991, so these years provide the best comparison for inter-annual variability.

Cumulative WPUE rates were two to ten times higher in the western Beaufort Sea than in the Chukchi Sea (Fig. 22). The recurrent sightings of aggregations of bowhead whales feeding east of Point Barrow in 1984 and 1989 resulted in the high cumulative WPUE values in the western Beaufort Sea from late September through mid-October. Overall, the temporal occurrence of bowheads described by western Beaufort Sea cumulative WPUE is in good agreement with peak calling rate periods derived from the analysis of bowhead calls recorded in conjunction with the 1987 fall migration (Moore et al. 1989a). Acoustic data sampling was limited to a 10-20 km zone just west of Barrow, so the agreement between the calling rates and sighting rates from data collected over a much broader area is somewhat surprising.



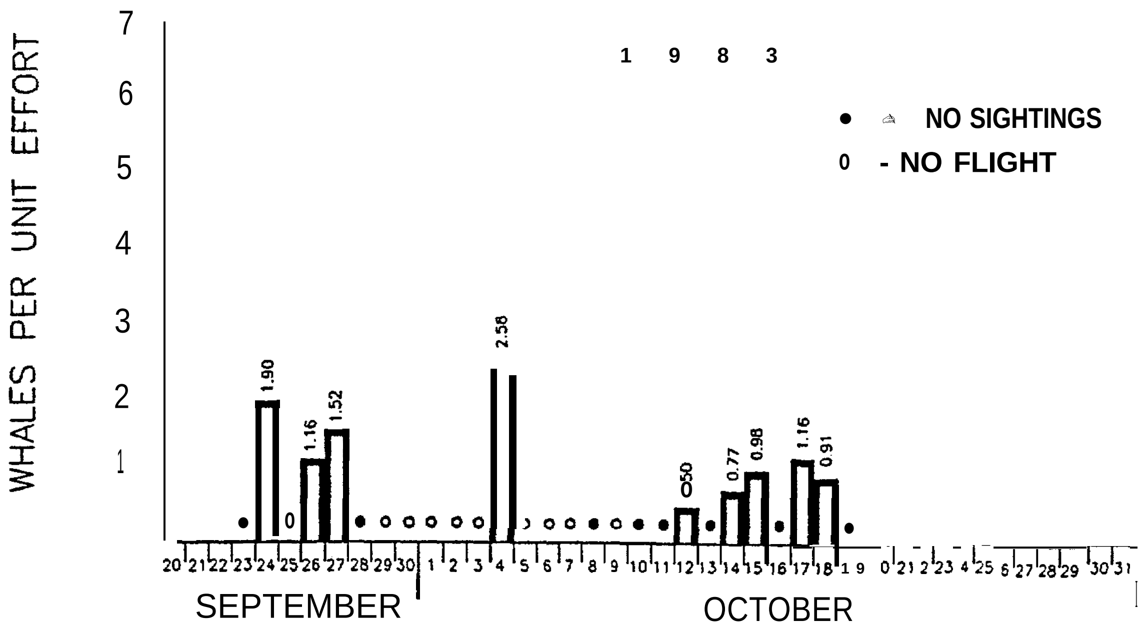
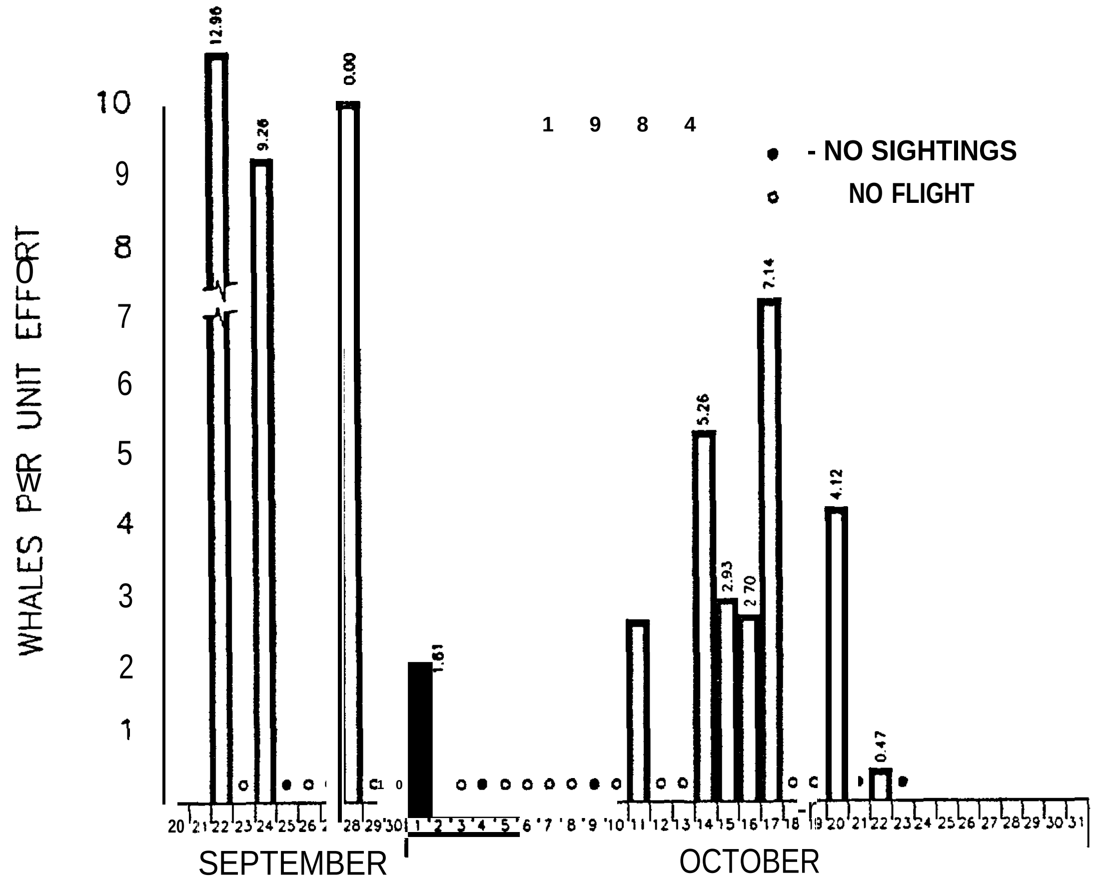
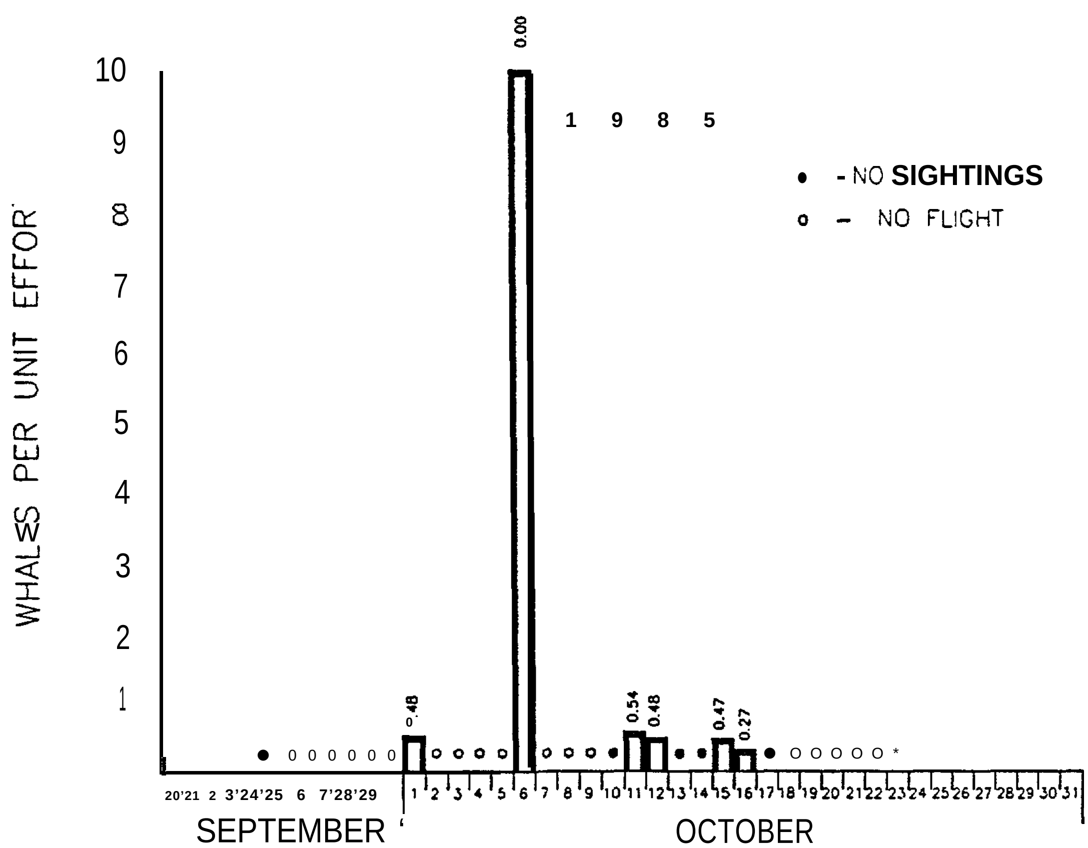


Figure 21. Annual bowhead whale daily WPUE in the study area, 1982-91.





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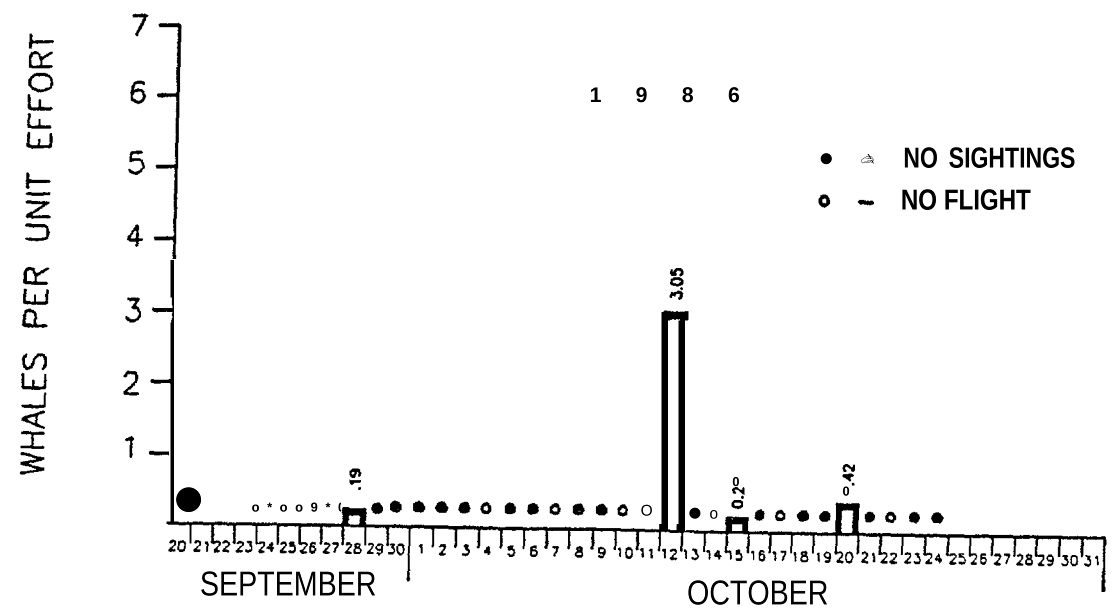

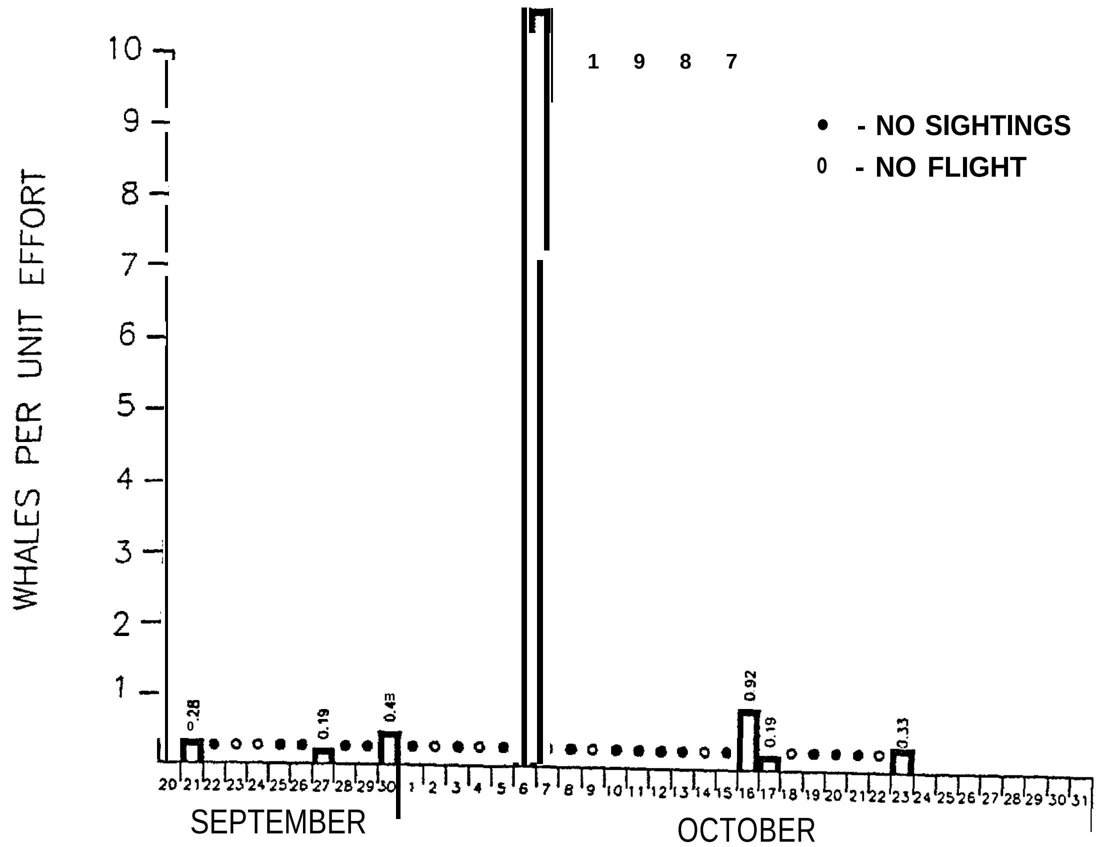

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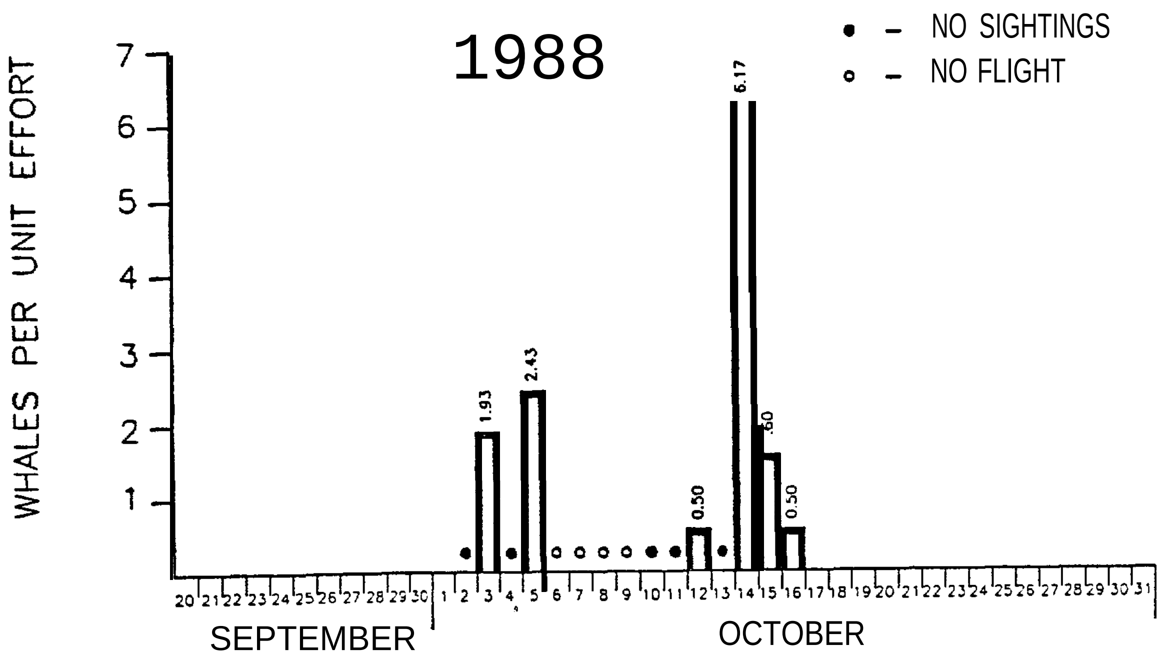

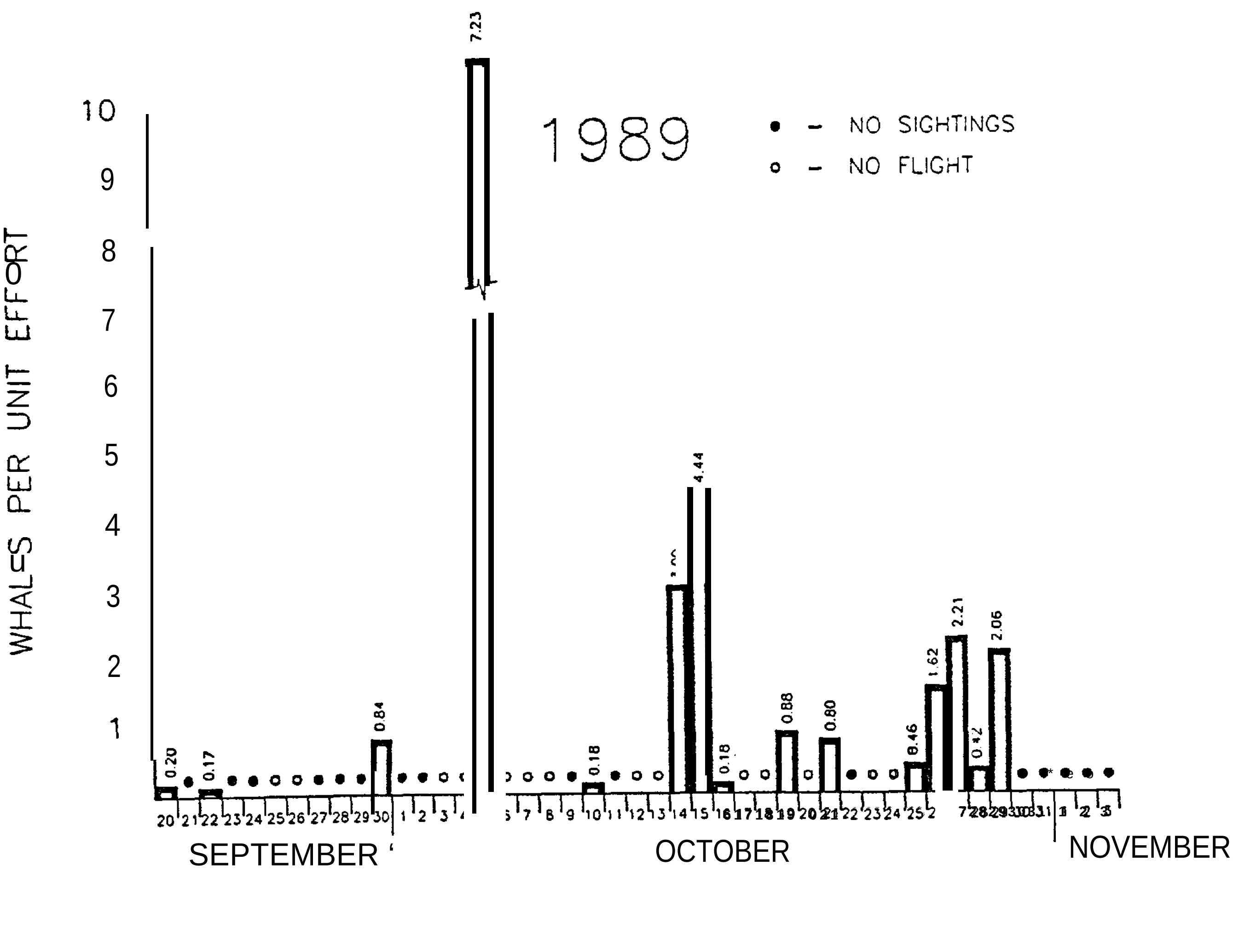

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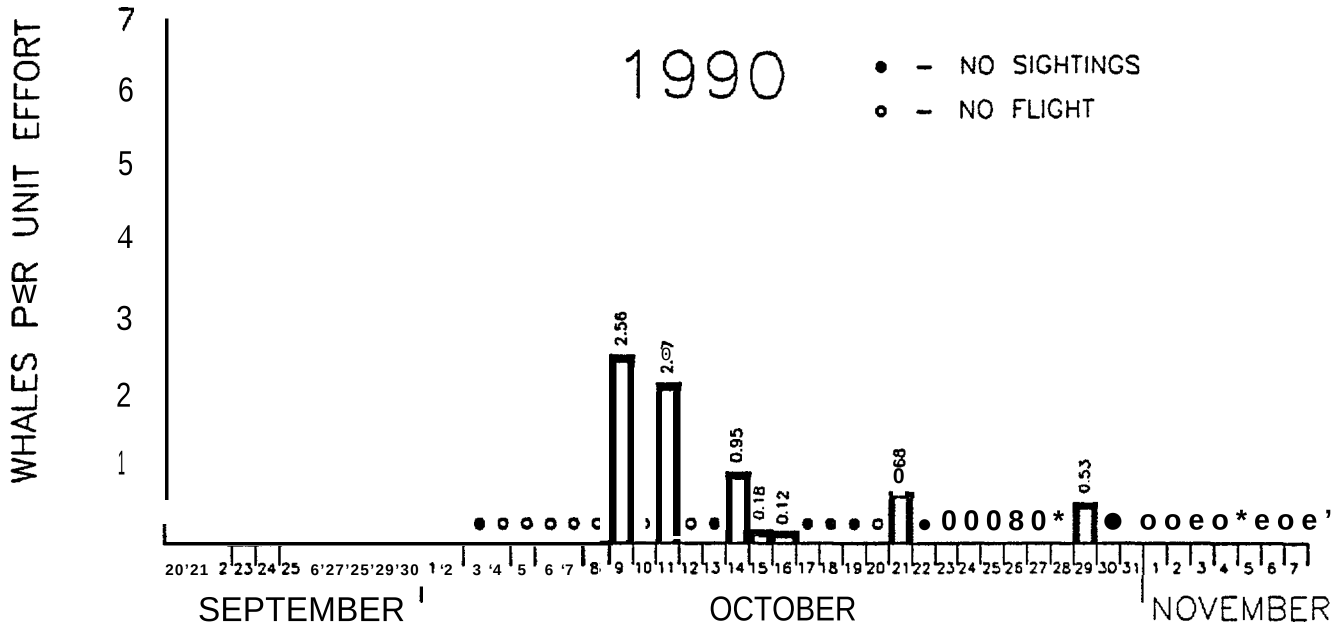

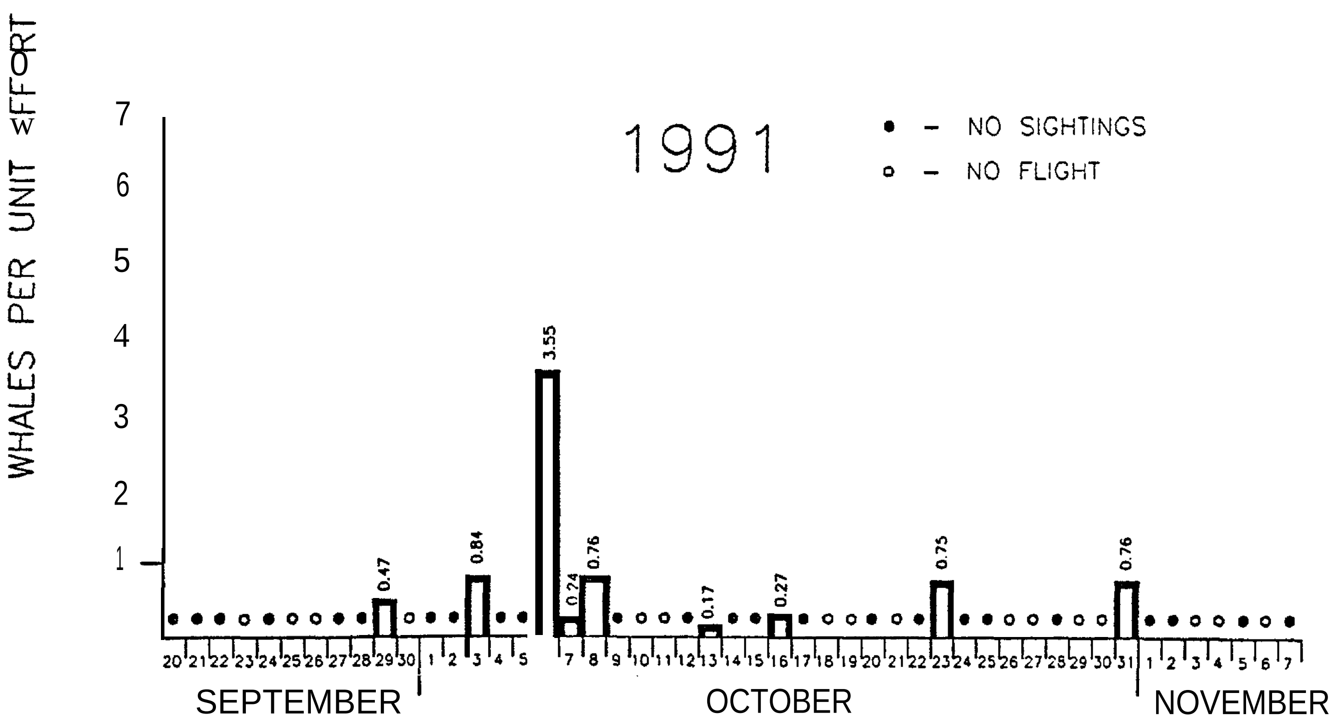

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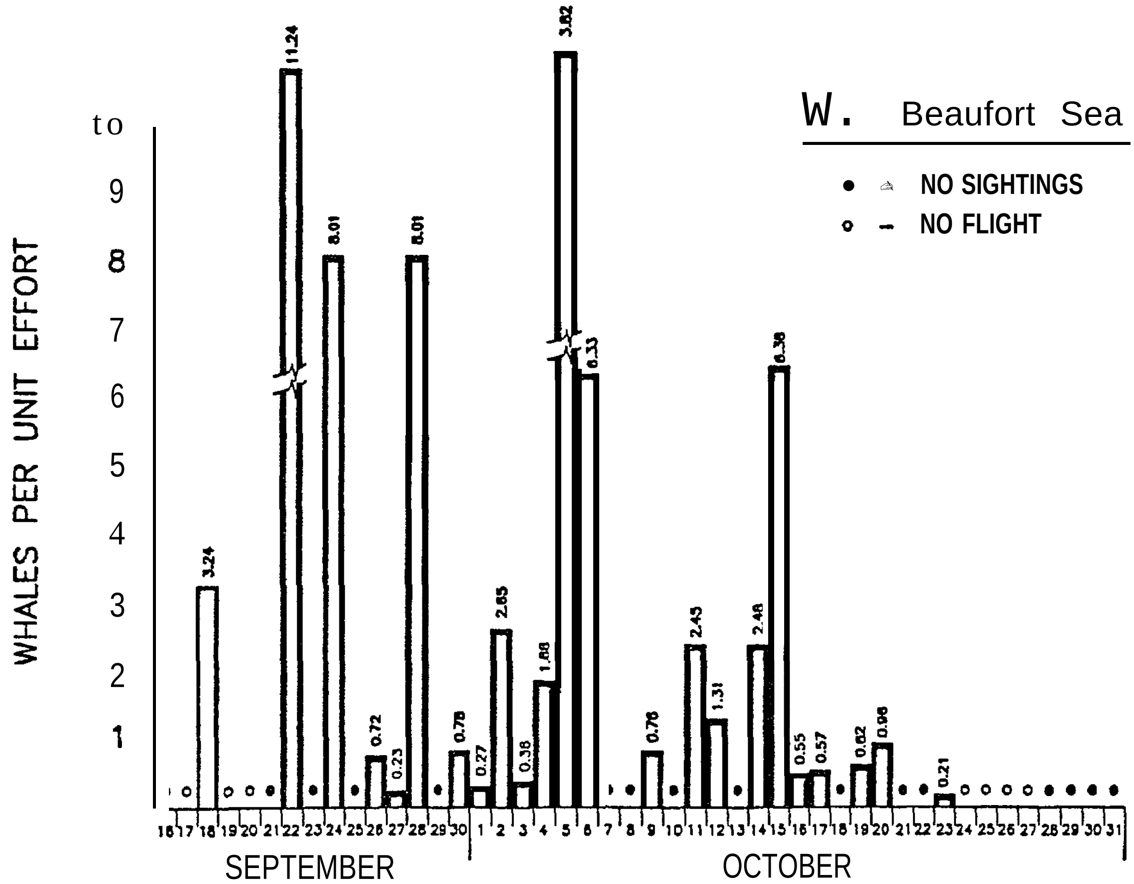


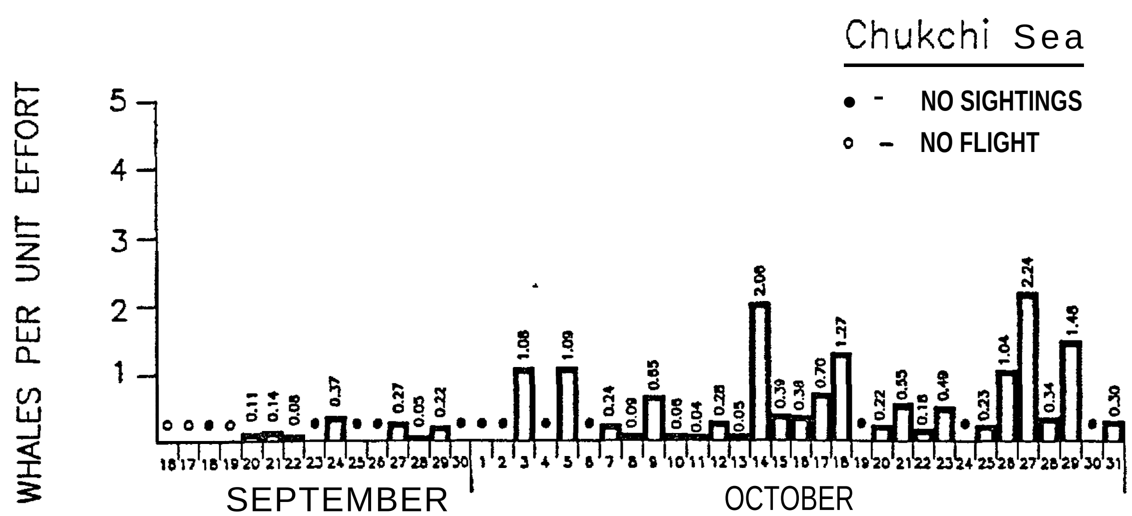


Figure 22. Cumulative {1982-91) bowhead whale daily WPUE in the western Beaufort and northeastern Chukchi seas.

Cumulative WPUE rates in the Chukchi Sea were comparatively low (Fig. 22). Highest rates were recorded in mid- and late October. This pattern of temporal occurrence suggests that bowheads pass through the northeastern Chukchi Sea throughout the fall, but do not seem to aggregate there as they sometimes dointhe western Beaufort Sea.

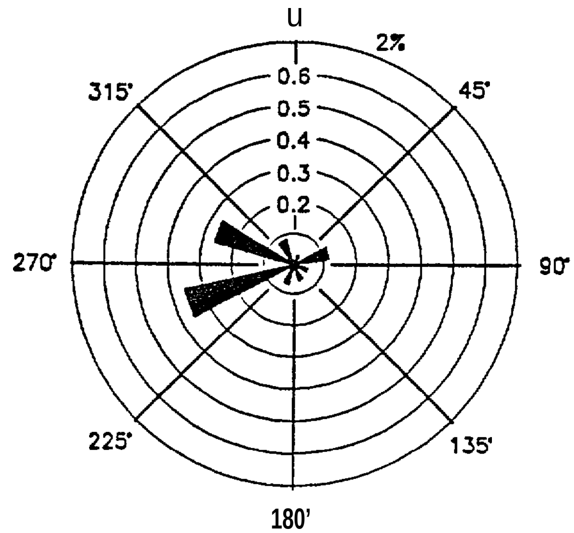
Aprimarytask of this study istodefine the bowhead whale fall migration route across the Chukchi Sea and determine if the route is affected by OCS oil and gas development activities. Bowhead migration route is described by: (a) an analysis of swimming direction; and (b) fitting lines to random sighting data using the method of least squares regression (Zar 1984). As described in Methods, lines were fit only for years with three or more random sighting locations west of 156" 30'W and south of 720 N latitude; therefore 1985 (n= 1), 1986 (n= 2), 1987 (n= 2) and 1990 (n= 2) were excluded from the analysis. However, all bowhead rSI data south of720 N (n= 60 rSI) were incorporated into the cumulative (1982-91) line fit, with a second line fit to cumulative rSI data north of 72" N (n=6 rSI).

It is important to note that descriptions of migration route derived from swimming direction analyses and lines fit to observed rSI distribution cannot describe the migration route taken by individual whales. Indeed, tagging studies have demonstrated that bowheads migrating across the Beaufort Sea in fall may stop for several days in one area, then cross a relatively broad expanse in only a few days on a less-than-direct course (Wartzok et al. 1990). In the absence of tracking studies, however, these descriptions of migration route provide a baseline against which to compare future observations of bowhead whale occurrence in the Chukchi Sea.

Bowhead whale swimming direction was significantly clustered about 272 "T **(p <().001;n=111) in** the western Beaufort Sea, and about 248 "T (P< 0.001; n =77) in the northeastern Chukchi Sea (Fig. 23). The strong statistical significance in both data sets implies that most bowheads approach Point Barrow on a westerly course, then turn and swim southwest after passing the Point. Indeed, the two swimming direction data sets

BEAUFORT SEA

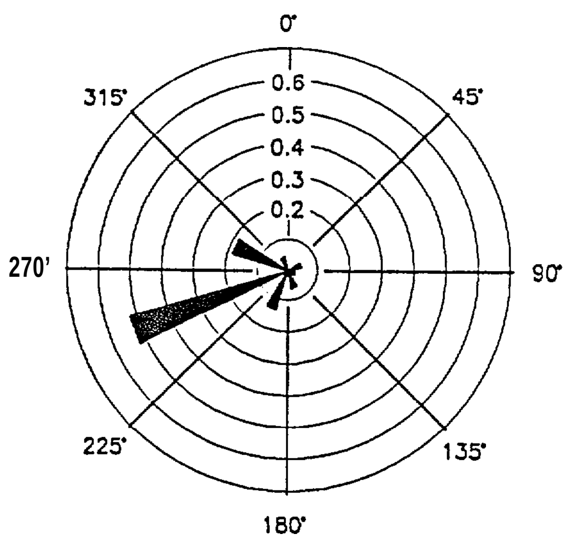
n = **111**



a = 272°T, r = 0.51
z = 29.39, p < 0.001

CHUKCHI SEA

n = **77**



a = 248°T, r = 0.74
z = 42.23, p < 0,001

Figure 23. Cumulative (1982-91) bowhead whale swimming direction in the western Beaufort and northeastern Chukchi seas.

were significantly different from each other (Watson U^2= 0.356, p< 0.002), which further supports this contention. Bowheads seen north of 72 ° N latitude in the north-central Chukchi Sea do not seem to fit this paradigm, however. Although bowheads seen north of 72 ° N latitude were incorporated in the overall swimming direction analysis (Fig. 23), individually these whales exhibited headings between 1800 and 300” T, with an average swimming direction of 267 “T (r= 0.73, p <0.05; n =6). There was no statistical difference between bowhead swimming direction for data sets north and south of 720 N in the Chukchi Sea (Watson U^2=0.030, p< 0.50), suggesting that whales seen to the north may be part of a general southwest dispersion pattern rather than a dichotomous component of the migration.

Linear regression analysis of annual bowhead rSI west of Point Barrow (1560 30'W) and south of 720 N indicated a provisional southwest migration axis for each year, although the linear regression was not significant in three of the six years tested (Table 17; Fig. 24). The statistical fit and westward extent of the annual lines varied with the available data. In some years (eg. 1984, 1989, 1991), one sighting strongly influenced line length and slope. Also, when random sighting data north of 72” N were added to the data set for the years 1989 (n =4) and 1990 (n =2), line slopes were directed northwest, in contrast to the average southwest swimming direction each year. Therefore, a separate line was fit to ‘northern’ data for 1989, but the fit was not statistically significant (F= 0.63, p =0.51). No lines were fit for 1990 due to insufficient sample size (n =2 rSI) in the ‘northern’ rSI data sets.

There was no significant difference (F=1.59, p< 0.50) in bowhead whale migration axes among the three years where the axes, as defined by line slopes, were statistically significant (i.e., 1983, 1988 and 1989; Fig. 25A). In addition, there was no significant difference in line elevation (F= 1.14, p <0.50), indicating that whales entered the Chukchi Sea (i.e., crossed the 156°30'W longitude line) at about the same latitude in each of the three years. The line fit to cumulative (1982-91) bowhead rSI data south of 720 N was directed southwest (Table 17; Fig. 25 B), complementing swimming direction analysis for bowheads in the northeastern Chukchi Sea (see Fig. 23). Also, there was no significant

Table 17. Sample size (rSI), line slope (b), coefficient of determination (r^2) and statistical significance (F [p= value]) for lines fit to bowhead rSI south of 720 N to describe provisional fall migration axes in the Chukchi Sea, *Sample size insufficient for linear regression analysis. tine fit not statistically significant.

YEAR	rSI	b	r^2	F	[p = value]
1982	9	0.380	0.159	1.33	[0.287]
1983	7	0.134	0.814	21.87	[0.006]
1984	5	0.143	0.324	1.44	[0.317]
1985	1*				
1986	2*				
1987	2*				
1988	13	0.101	0.680	23.38	[0.0005]
1989	12	0.068	0.618	16.18	[0.0024]
1990	2*				
1991	7	0.052	0.208	1.31	[0.3037]
1982-91	60	0.103	0.568	76.19	[< <0.0005]

difference in line slope among the three years 1983, 1988 and 1989 and the cumulative (1982-91) slope ($F = 0.63, p < 0.50$). The line fit to cumulative bowhead rSI north of720 N ($n = 6$) was directed northwest, in contrast to the swimming direction for those whales, but the fit was not statistically significant ($F = 0.08$, $p = 0.80$; Fig. 256).

The results of the line-fitting analyses point out the problem of trying to detect shifts in migration axes from data collected during broad-scale aerial surveys. Although no difference in migration axes can be described for years 1983, 1988 and 1989, or among those years and the migration axis described from the cumulative (1982-91) data, this may be due to sampling or analytical weaknesses. First, annual sample sizes of bowhead whale rSI in the Chukchi Sea were often too small to provide a statistically meaningful data set for analyses. Small sample sizes are likely a function of a) the broad area targeted for survey; b) fall-weather limitations to aerial survey sampling in the Chukchi Sea; and c) bowhead whale behavior, which appears to be largely migratory rather than aggregative. Second, even relatively small changes in sampling regime, such as adding

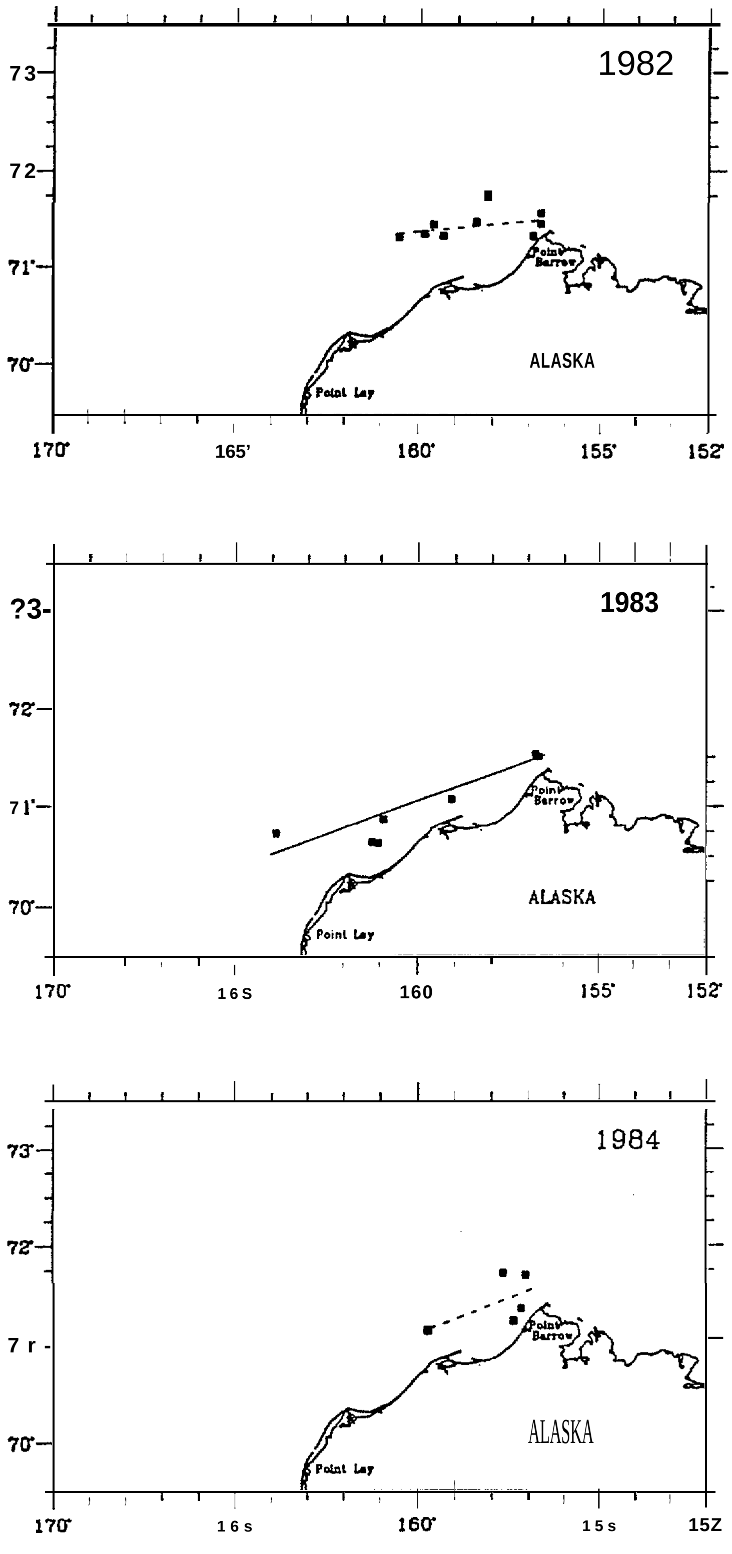
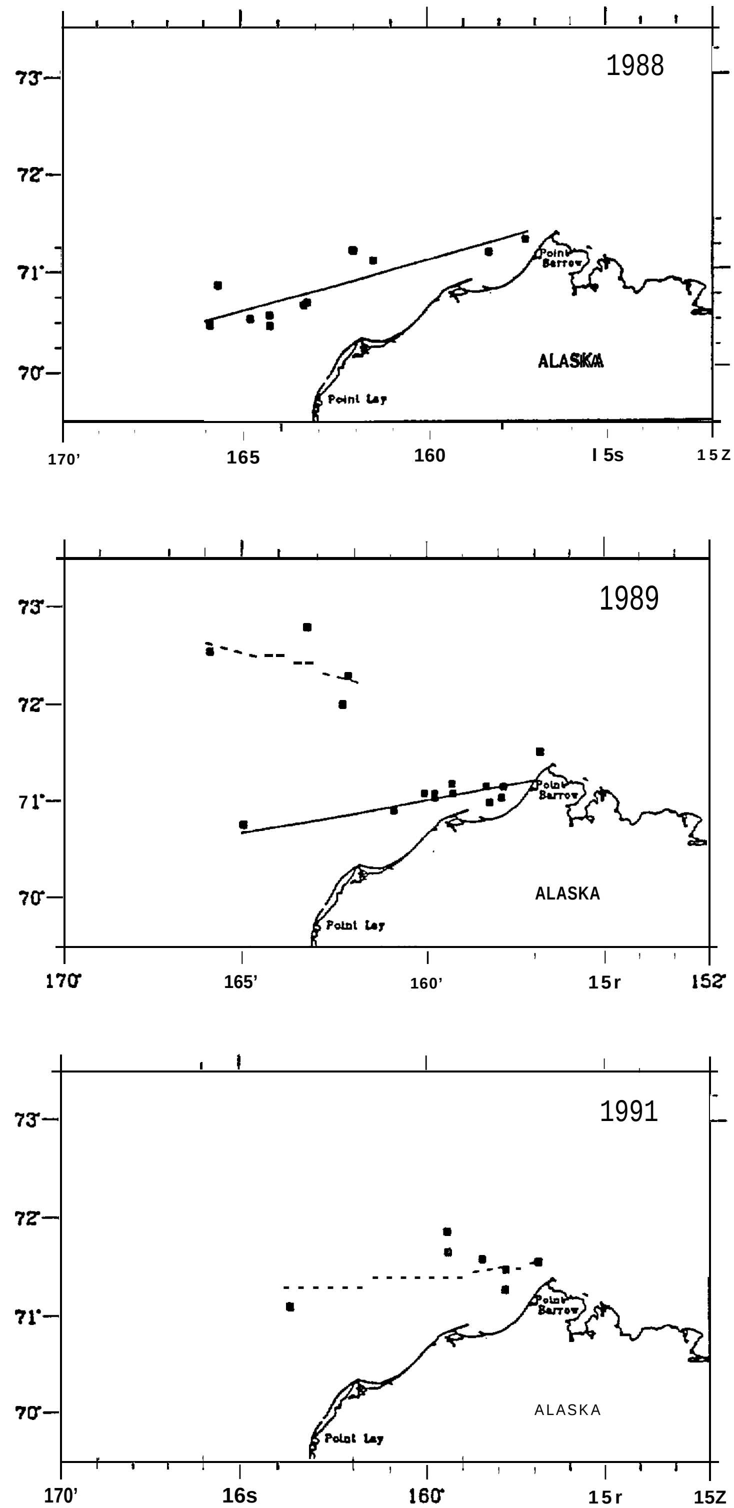


Figure 24. Provisional annual migration axes for bowhead whales in the Alaskan Chukchi Sea, described by lines fit to random sightings (rSI) west of point Barrow (156030'W) for each year 1982-91 where rSI > 3. Dashed lines indicate line fits that were not statistically significant (see Table 17).



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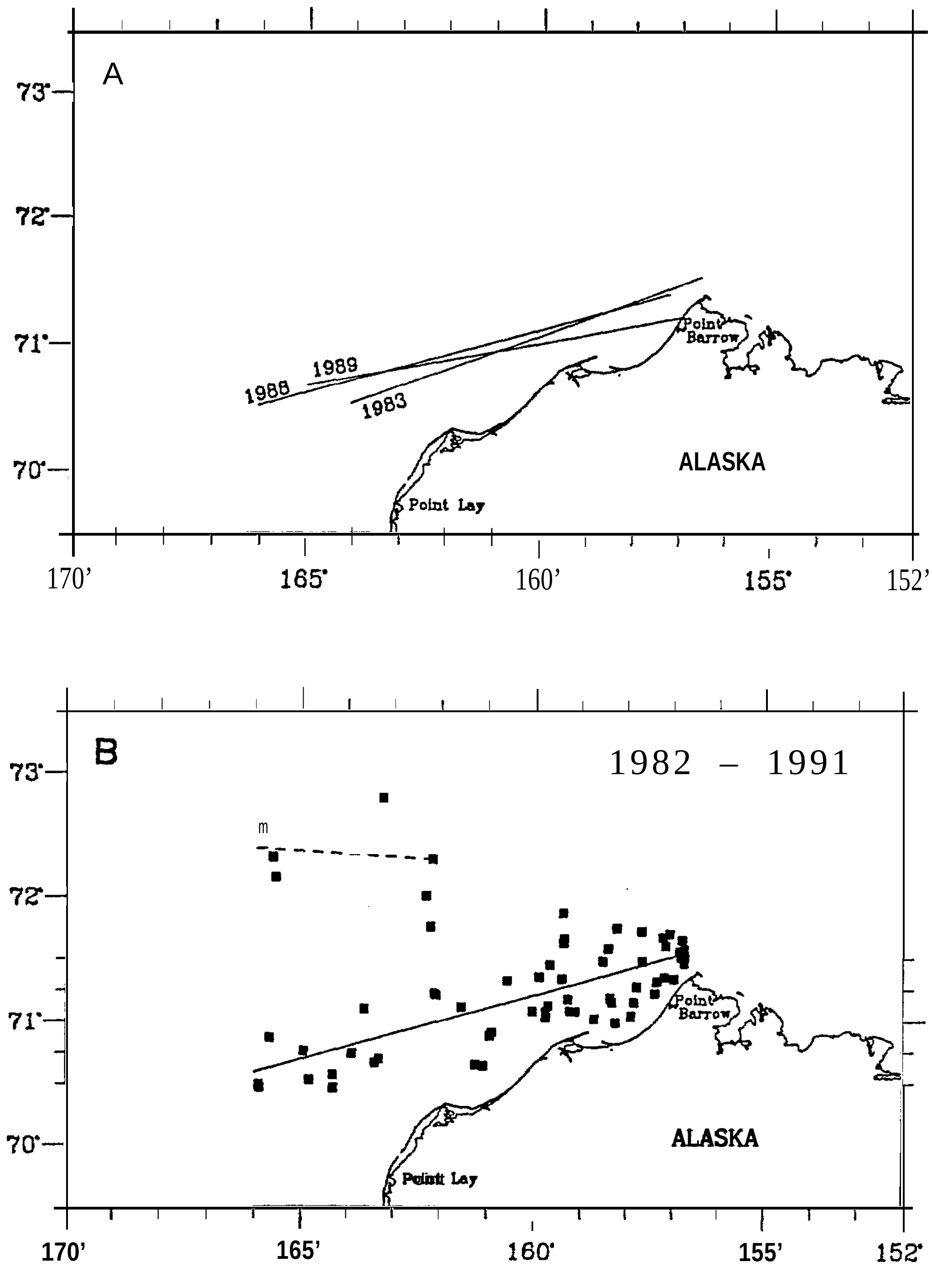


Figure 25. Lines representing provisional bowhead whale annual migration axes for 1983, 1988 and 1989 (A), and for the cumulative (1982-91) bowhead rSI data in the Alaskan Chukchi Sea (B).

10 of latitude to the study area (blocks 12 N-l 6N) during the last four years of the study (1988-91), resulted in inconsistencies in the data set that are difficult to resolve during analyses. For example, the disagreement between line slope and observed swimming direction for whales seen north of 72* N is difficult to interpret due to the small sample size. As with the swimming direction analysis, the line fitting analysis of bowhead rSl north of 720 N suggests that some bowheads either continue to swim northwest after passing Point Barrow, or they enter the Chukchi Sea study area from the north. Neither of these suggestions is strongly supported by observation. Although whales exhibiting northwesterly swimming directions (i.e. 270-3100 T) have been observed west of Point Barrow, the predominant swimming direction in the Chukchi Sea is strongly clustered about a southwest heading (see Fig. 23). In addition, bowhead distribution and survey block WPUE indicates most whales pass Point Barrow close to the coast (i.e., occur in survey blocks 12 and 13) rather than farther offshore (i.e., in survey blocks 12N and 13 N). However, five bowhead whales including two calves were observed just north of survey block 14N in 1990, suggesting that some whales may enter the Chukchi Sea study area from the north.

The bowhead whale migration route across the Chukchi Sea may be directly or indirectly influenced by currents. Temperature and salinity differences among water masses on the Chukchi shelf may provide direct cues to migrating bowheads. Two principal water masses enter the Chukchi Sea through the Bering Strait (Aagaard 1987): the saline Bering Sea water (BSW) and the hyposaline Alaskan Coastal water (ACW). The inflow of the two water masses diverges near the latitude of Point Hope (Fig. 26). Both flow northward along bathymetrically guided routes, the ACW to the northeast along the Alaskan coast, and the BSW through Herald Canyon in the central Chukchi Sea, west of the study area. Filaments of the ACW branch off the main coastal flow at three locations: west of Point Lay (<u>ca</u>. 69 “30’N, 1670 W), west of Peard Bay (<u>ca</u>. 710 N, 1620 W), and northwest of Point Barrow (<u>ca</u>. 71 “ 30’N, 157” 30’W). Swimming direction and line-fitting analysis suggest that most whales migrate along the northeastern branches of the ACW west of Point Barrow. Whales seen in the north-central Chukchi Sea study area may be influenced by fronts created where the ACW meets resident Chukchi Sea water (RCW)

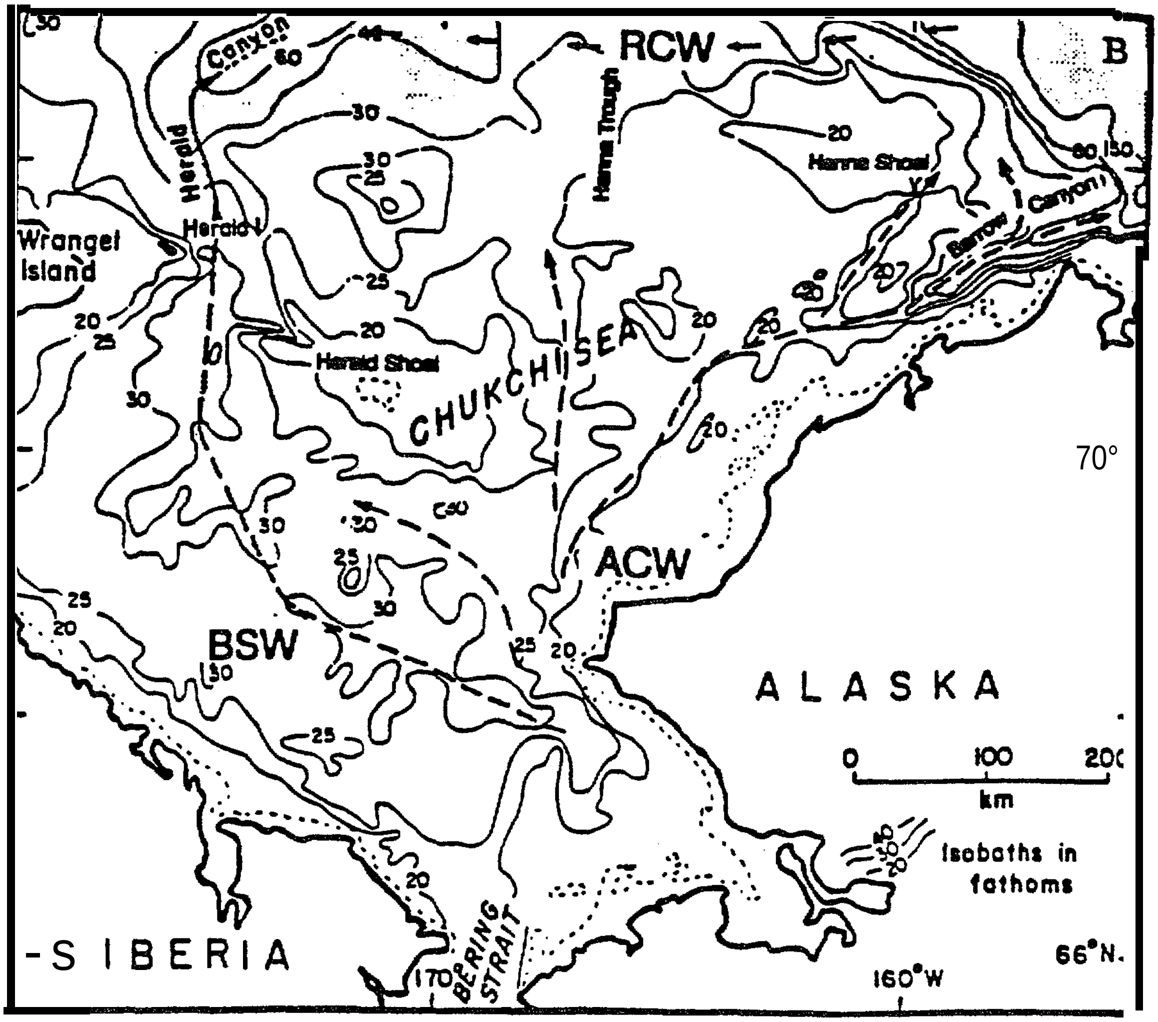


Figure 26. Bathymetry (in fathoms) and major currents (arrows) in the Chukchi Sea (from Bourke 1983).

associated with the ice edge. Barrow Canyon (and probably Herald Canyon) are sites of dynamic exchange of sea water between the Chukchi shelf and the Arctic basin (Aagaard and Roach 1990). Factors influencing water mass fluxes at Barrow Canyon may also influence the bowhead migration route west of Point Barrow.

Current flow and ice conditions throughout the Chukchi Sea appear to vary greatly with wind conditions (Aagaard 1987; Muench et al. 1991). Although the underlying cause for the northward flow through the Bering Strait is the higher sea level in the North Pacific relative to the Arctic Ocean, major differences in flow rate are driven atmospherically with summer transport about 50 percent greater than during the winter (Aagaard 1987). Mean monthly flow rates in September and October are nearly identical to those in April and May, and are only about half that of peak inflow in July. Therefore, bowheads would not **be** swimming against a strong **current inflow** in fall. If the bowhead migration route is, in **part,** current-influenced, annual variability in atmospheric conditions may lead to variability in migration route.

The location of oceanic fronts, like the ice edge, varies annually in the Chukchi Sea (Paquette and Bourke 1981), The inflow of relatively warm southern water through the Bering Strait directly influences the irregular contour of the ice edge. Embayments in the ice edge occur in roughly the same places year after year over relatively deep-water troughs, for example near 167" W (Bourke 1983). A sharply-defined surface boundary is formed roughly parallel to the ice edge where ACW meets RCW (Bourke 1983). Fronts do not always coincide exactly with the ice edge, however, because wind-driven ice moves faster than the fronts and can overlie or drift some distance away (<10 km) from the front. At the core of the ACW intrusion, warm southern water often flows strongly enough to penetrate far into the ice edge, with filaments of the warm water flow measured in October as far north as 73" N north to of the Bering Strait and to 72" 30'N north of Point Barrow (Ahlnas and Garrison 1984).

Current pattern may indirectly affect bowhead migration route by creating fronts where whale prey may become concentrated (Fissel et al. 1987; Borstad et al. 1987). Fronts, formed where differing water masses abut, can occur over spatial scales as small as tens of meters and are often the sites of intense biological activity (Bowman and Esaias 1978; Parsons et al. 1977). Further, potentially high nutrient levels can occur when two currents meet and diverge, causing upwelling. The convergence of oceanic fronts and eddies have been hypothesized to be good baleen whale feeding areas (Nasu 1974; Gaskin 1982). Specifically, bowhead whales appear to rely on finding relatively dense patches of prey associated with water mass boundaries, at least in the eastern Beaufort Sea (Richardson 1987). Bowheads continue to feed in fall as they migrate west across the Beaufort Sea, with one record of feeding in the Chukchi Sea west of Barrow in

September 1983 (Ljungblad et al. 1986b). Migrating along a route where oceanographic fronts are expected may provide bowheads with feeding opportunities throughout the fall.

Calf Sightings

There were 14 sightings for a total of 16 bowhead whale calves in the study area from 1982-91 (Fig. 27). No calves were seen in 1982, 1985, and 1987; sightings in other years ranged from one to four. Calf distribution was similar to that for all whales. Of particular note were two calves seen just north of730 N in 1990,

All calves were seen in October, with no significant difference in calf sighting rate between the first and second half of the month ($\chi^2 = 0.77, p < 0.50$; Table 18). These results are similar to those for the Alaskan Beaufort Sea, where no geographic or temporal segregation in calf occurrence was described for four years (1 982-85) of sighting data (Clarke et al. 1987). Annual variability in calf number or distribution may obscure spatial or temporal segregation (Nerini et al. 1984). Segregation of cow-calf pairs occurs during the spring migration past Point Barrow (Rugh 1990), and was documented at least one year on the summer feeding grounds in the Canadian Beaufort Sea (Cubbage and Calambokidis 1987). Further, Eskimo whalers at Kaktovik, Alaska report that cows with calves pass Barter Island later in the season than other whales (Braham et al. 1984). This tendency for cows and calves to occur later in the fall migration is supported by the lack of September calf sightings in the Chukchi Sea study area.

Behavior

Observed bowhead behaviors in the study area were nearly equally divided between migratory and social (Table 19). Swimming was observed most often (44%, n =241) with feeding (33%, n =182) the next most common activity. Feeding was observed most often in late September, and was largely confined to the western Beaufort Sea (Fig. 28). The overall number of feeding whales was strongly influenced by the bowhead aggregations seen near Point Barrow in 1984 (n= 140) and 1989 (n =30). Little feeding activity was seen there, or anywhere else in the study area, in other years. Nine

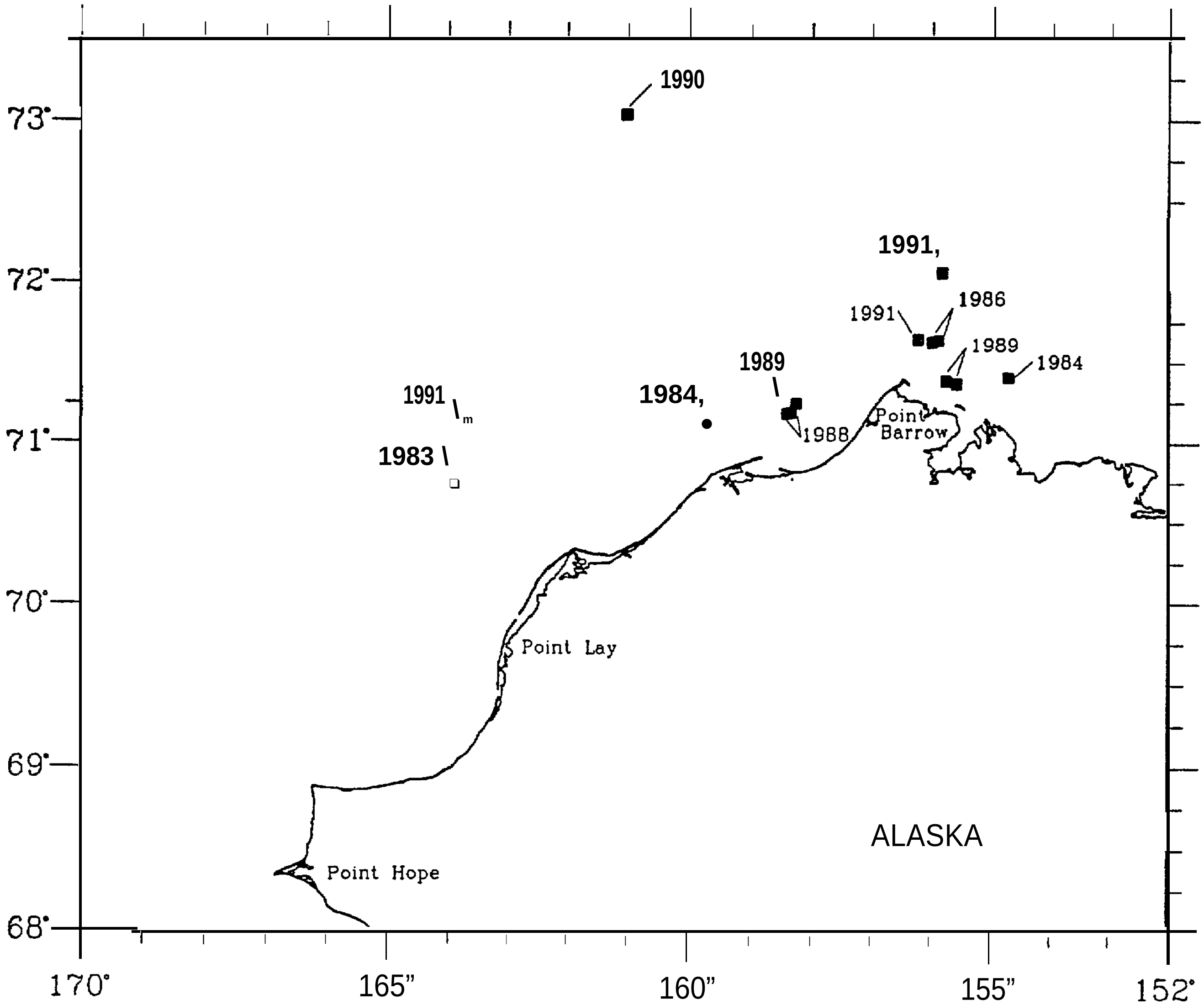


Figure 27. Distribution of 14 sightings for a total of 16 bowhead whale calves in the study area, 1982-91.

bowheads were seen feeding in block 13 in 1983 and three whales were seen feeding north of Smith Bay in 1987.

Waters east of Point Barrow maybe inconsistent in annual productivity, a possible explanation of the intermittent observations of bowheads feeding there. Prior to 1989, bowhead feeding aggregations were seen east of Point Barrow in 1984, 1978, and 1976, and Durham (1979) reported that Eskimo whalers occasionally saw groups of 50 to 60 whales near Point Barrow in the fall (summarized in Ljungblad et al. 1986a). Euphausiids were the prey most common in the stomachs of bowheads taken near Point Barrow in fall (Lowry and Frost 1984). Euphausiids maybe entrained from the northern Bering Sea

Table 18. Semi-monthly summary of calf number and sighting rate (cSR = no. calves/survey hour) in the study area, 1982-91. * = sighting rate was not calculated for 1990 because the calves were seen north of the study area.

	1-15 October No. (SR)	16-30 October No. (SR)	TOTAL No. (SR)
1982	0	o	o
1983	0	1 (0.06)	1 (0.02)
1984	1 (0.08)	1 (0.09)	2 (0.05)
1985	o	o	o
1986	2 (0,06)	0	2 (0.03)
1987	o	0	o
1988	2 (0.04)	0	2 (0.04)
1989	3 (0.10)	1 (0.02)	4 (0.03)
1990	2 (-)*	o	2 (-)*
1991	3 (0.05)	0	3 (0.03)
1982-91	13 (0.04)	3 (0.01)	16 (0.03)

in the ACW, their number influenced by annual variability in current speed and direction, which seems associated with wind forcing at the Bering Strait (Coachman and Aagaard 1988). Other oceanographic factors probably affect euphausiid availability near Point Barrow, but the influence of physical factors on zooplankton abundance is poorly understood. The Point Barrow area incorporates a topographic promontory, a steep shelf break (Barrow Canyon), a topographic eddy, and the convergence of the Alaska Coastal Water (ACW) and the Beaufort Sea gyre. Current flow along the Chukchi coast is usually northeastward, but local wind conditions can cause flow reversals resulting in coastal upwelling (Johnson 1989). In addition, Barrow Canyon is an area of dynamic exchange of water masses, resulting in the up-canyon flow of warm saline water onto the shelf in some years (Aagaard and Roach 1990). Any, or a combination of all, of these factors may influence the availability of bowhead whale prey, and thereby feeding opportunities near Barrow each fall.

Table 19. Semi-monthly summary of bowhead whale behavior, 1982-91.

	16-30 SEP No (%)	1-15 OCT No. (%)	16-31 OCT No. (%)	TOTAL No. (%)
MIGRATORY				
Swim	39 (21)	147 (56)	55 (57)	241 (44)
Dive	2 (1)	8 (3)	3 (3)	13 (2)
SOCIAL				
Rest	3 (1)	16 (6)	6 (6)	25 (5)
Mill	3 (1)	6 (2)	0	9 (2)
Display	5 (3)	12 (5)	17 (18)	34 (6)
Cow-calf	0	25 (9)	6 (6)	31 (6)
Feed	138 (73)	35. (13)	9 (9)	182 (33)
N/R	0	16 (6)	1 (1)	17 (3)
TOTAL	190	265	97	552

Display behaviors, including breaches, flipper-slaps and tail-slaps, were seen throughout the fall, but were most common in the latter half of October (Table 19). Breaching whales were seen alone and in groups; whales slapping the water with their flippers or tails were most often seen in groups. The function of such displays is largely unknown. Underwater sounds from breaches and slaps are not especially loud compared to bowhead calls (Wursig et al. 1989), so they would seem relatively inefficient for acoustic communication among whales. Wursig et al. (1989) suggest that displays probably have several functions including aggression or arousal of some type, or simply play. Play behavior is difficult to distinguish from other whale-whale interactions, and its description has been confined to interactions with inanimate objects (Wursig et al. 1989), Log-play activity was observed of one whale near the feeding aggregation northeast of Point Barrow in 1989 (Moore and Clarke 1990).

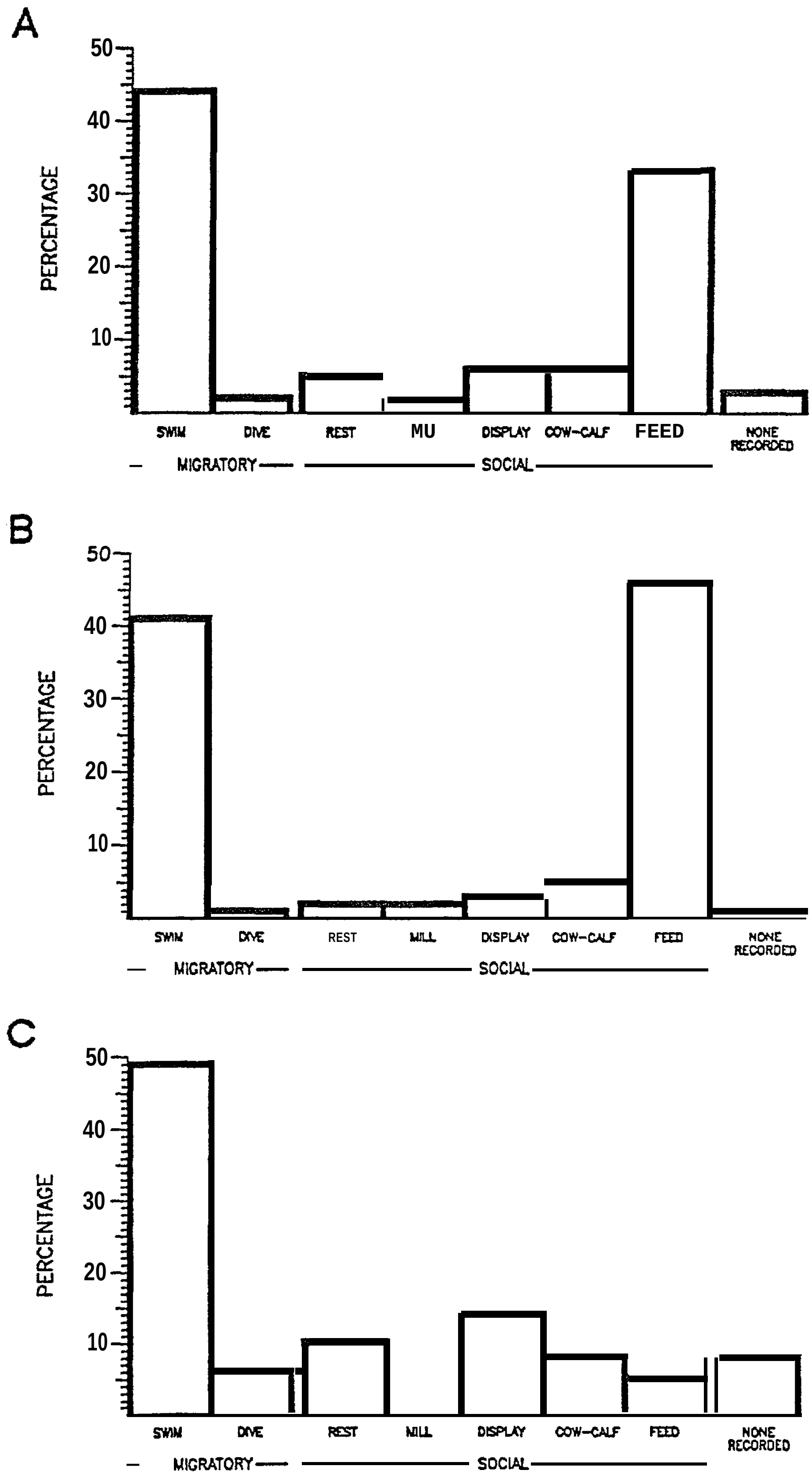


Figure 28. Summary of bowhead whale behavior in the overall study area (A), western Beaufort Sea (B) and northeastern Chukchi Sea (C), 1982-91.

Habitat Relationships

Bowheads were seen most often (64%, n =351) in water <37 m deep throughout the study area (Table 20). The number of whales in water <37 m in the western Beaufort Sea (57%, n=316) was influenced by the aforementioned occurrence of feeding whales east of Point Barrow in 1984 and 1989. This is not surprising, as bowheads feeding in fall were seen in significantly shallower water than non-feeding whales across the Alaskan Beaufort Sea (Ljungblad et al. 1986a). The percentage of rSI bowheads (11%) seen in shallow (<37 m) water in the northeastern Chukchi Sea (north of700 N, west of 157° W) was not significantly different ($\chi^2=0.65$, $p< 0.50$) from that expected based on the percentage of shallow water habitat (12%) available.

Bowheads were seen most often (66%, n =365) in open water or very light (0-10%) ice cover (Table 21). Overall, only 25 percent (n= 138) of all whales were seen in ice cover >70 percent. Whales were seen in heavy ice most frequently in 1982, 1983, 1988 and 1991. In general, bowheads were seen in whatever ice cover predominated during the survey season each year; i.e., whales were not seen 'along the ice edge', as is sometimes presumed. Inferences regarding the use of particular ice habitat by bowhead whales may be affected by changes in study area boundaries (Porter and Church 1987), as well as by the annual variability of the habitat within the study area, the timing of the survey season, and the ability of aerial observers to detect whales in various classes of ice cover.

Gray Whale

Distribution and Relative Abundance

There were 167 sightings for a total of 424 gray whales over nine survey seasons. No gray whales were seen in 1985, and the three gray whales seen in 1988 were those trapped in heavy ice north of Point Barrow (Carroll et al. 1989). One gray whale was seen during the abbreviated 1990 survey season just offshore at Barrow. There were 60 sightings for a total of 174 gray whales from 16-30 September, 63 sightings for a total of 115 gray whales from 1-15 October, and 44 sightings for a total of 135 gray whales from 16-31 October (Fig. 29). Gray whales were also seen immediately south of the study area

Table 20. Number and percent of bowhead whales in <37 m and ≥37 m water depths in the study area, 1982-91.

	W. Beaufort Sea			Chukchi Sea		
Year	<37 m	≥37 m	Range (m)	<37 m	≥37 m	Range (m)
1982 (n=30)	12 (40)	5 (17)	7-210	2 (11)	11 (36)	18-59
1983 (n= 50)	17 (34)	9 (18)	7-199	4 (8)	20 (40)	29-97
1984 (n=192)	172 (89)	13 (7)	7-221	o (o)	7 (4)	38-91
1985 (n=10)	4 (40)	3 (30)	13-144	1 (10)	2 (20)	27-38
1986 (n=15)	7 (47)	4 (27)	9-181	2 (13)	2 (13)	20-42
1987 (n=32)	25 (78)	4 (12)	9-181	o (o)	3 (9)	51-75
1988 (n =55)	o (o)	3 (2)	134	2 (4)	50 (91)	33-91
1989 (n=117)	74 (63)	1 (1)	9-144	15 (12)	27 (23)	18-101
1990 (n=19)	3 (16)	4 (21)	18-181	o (o)	12 (63)	17-115
1991 [n =32)	2 (6)	14 (44)	11-247	9 (28)	7 (22)	15-123
Total (n= 552)	316 (57)	60 (11)	7-247	35 (6)	141 (26)	15-123

Table 21. Number and percent of bowhead whales in each ice cover class in the study area, 1982-91. Ice cover class = percent of surface area covered by ice.

Ice Cover Class	1982 No.(%)	1983 No.(%)	1984 No.(%)	1985 No.(%)	1986 No.(%)	1987 No.(%)	1988 No.(%)	1989 No.(%)	1990 No.(%)	1991 No.(%)	Total No.(%)
o-1o	9 (30)	17 (34)	168 (88)	10 (100)	12 (80)	31 (97)	3 (5)	90 (77)	17 (90)	8 (25)	365 (66)
11-20	o	o	o	0	0	o	o	1 (1)	o	o	1 (<1)
21-30	0	0	1 (1)	o	0	0	o	0	0	2 (6)	3 (1)
31-40	0	3 (6)	5 (2)	o	0	0	0	0	0	4 (13)	12 (2)
41-50	2 (7)	o	7 (4)	o	2 (13)	0	0	1 (1)	0	o	12 (2)
51-60	o	0	2 (1)	o	0	0	1 (2)	o	0	1 (3)	4 (1)
61-70	4 (13)	11 (22)	0	0	0	0	0	0	1 (5)	1 (3)	17 (3)
71-80	7 (23)	8 (16)	0	0	1 (7)	1 (3)	18 (33)	7 (6)	o	3 (9)	45 (8)
81-90	7 (23)	11 (22)	2 (1)	o	0	o	10 (18)	3 (2)	0	4 (13)	37 (7)
91-99	1 (4)	o	7 (4)	o	0	0	23 (42)	15 (13)	1 (5)	9 (28)	56 (lo)
Total	30	50	192	10	15	32	55	117	19	32	552

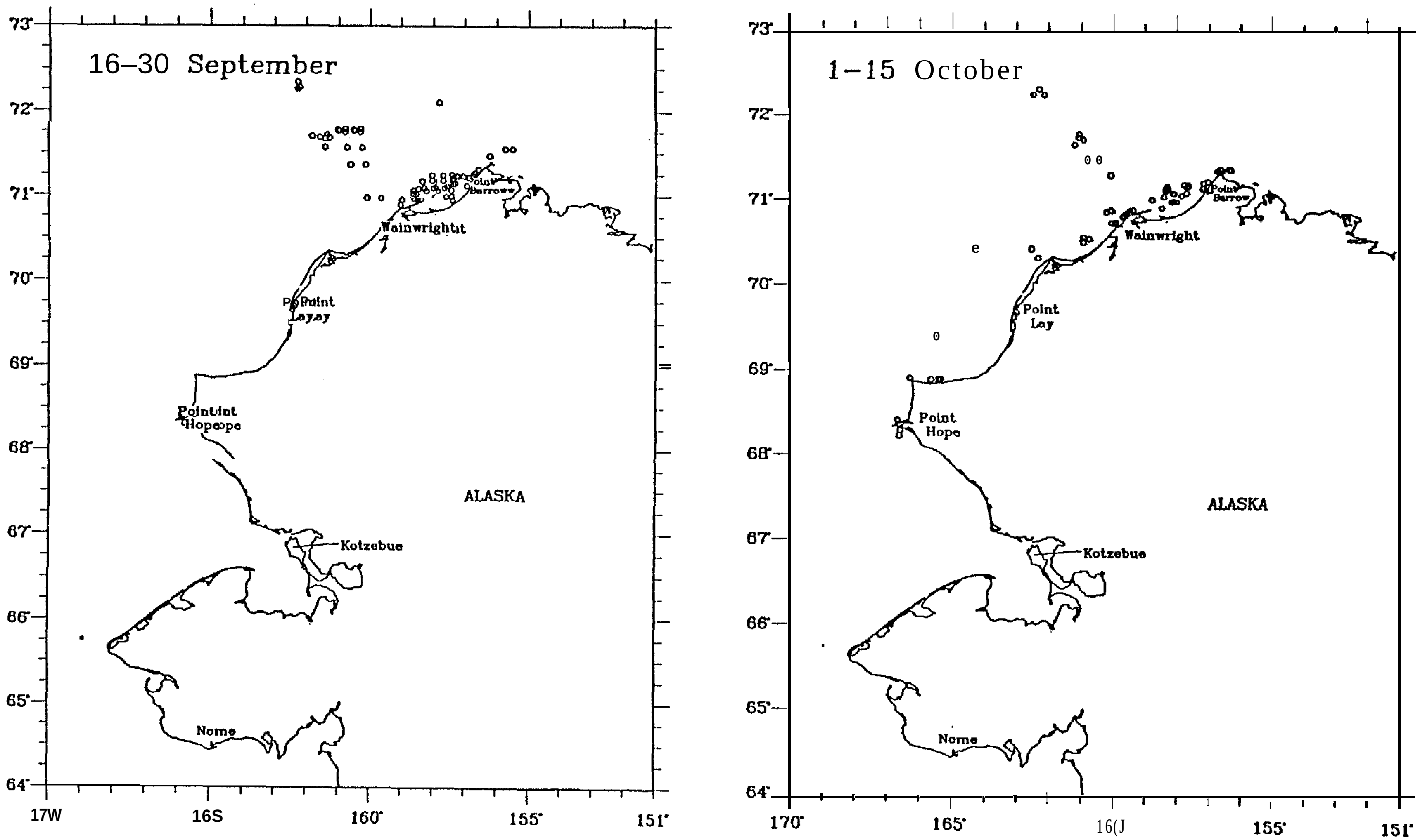


Figure 29. **Cumulative (1982-91) gray whale distribution relative to OCS lease areas depicting 60 sightings** for a total of 174 whales, 16-30 September; 63 sightings for a total of 115 whales, 1-15 October;

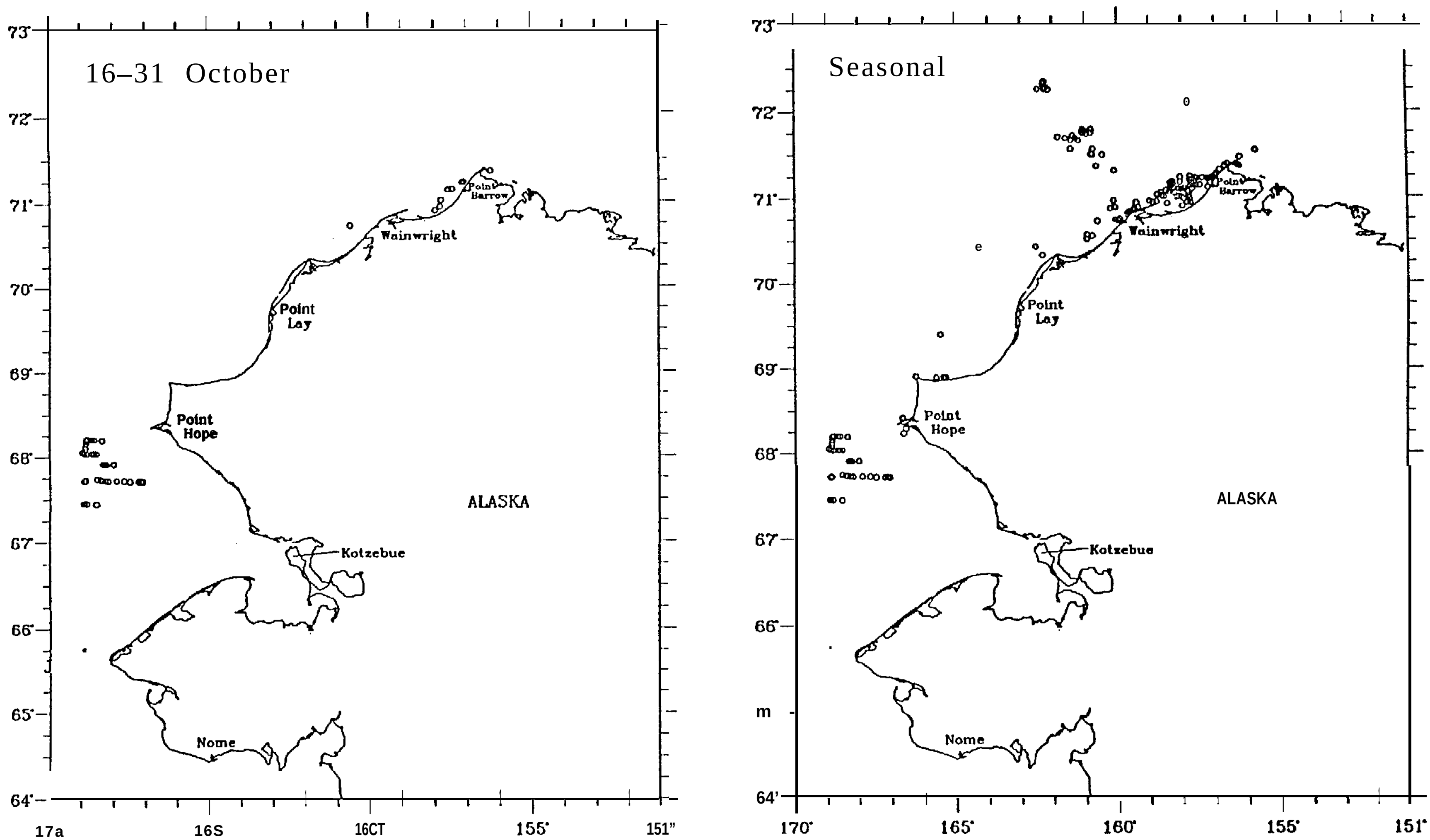


Figure 29. Cumulative **(1982-91**) gray whale distribution relative to OCS lease areas depicting 60 sightings for a **total of 174 whales, 16-30 September; 63 sightings** for a total of 115 whales, 1-15 October;

in November 1980 (Clarke and Moore in press). Gray whale distribution and relative abundance **in the study area from** July through early September 1982-87 are presented in Clarke et al. (1989) and are discussed here as appropriate.

Gray whale distribution was limited to three areas in the latter half of September: nearshore between Point Barrow and Point Franklin (ca. 70” 55’N, 155” W); offshore northwest of Point Franklin from 71030’ to 72 ◦30’N between 160”30’ and 1620 30’W; and along the coast at Point Hope (Fig. 29). Gray whale distribution during the first half of October was more widespread. Whales were seen along the coast between Point Barrow south to Icy Cape, northwest of Point Franklin (as in late September) and west of Icy Cape, and along the coast at Point Hope and Cape Lisburne. During the latter half of October, gray whale distribution was limited to nearshore waters between Point Barrow and Point Franklin, and the south-central Chukchi Sea southwest of Point Hope. Waters south of Point Hope were surveyed only in late October and November 1989-91, and high sea states often curtailed surveys in this area. Gray whales were seen in the southernmost Chukchi Sea, and between the Bering Strait and St. Lawrence Island in the northern Bering Sea, in late October and November 1980 (Clarke and Moore in press), suggesting that whales continue to feed in this area even as the southbound migration is underway in the southeastern Bering Sea (Rugh 1984).

The overall pattern of gray whale distribution highlights the importance of nearshore waters between Point Barrow and Point Franklin and offshore areas in the north-central Chukchi Sea. Gray whale distribution in offshore areas appears related to prey availability near Hanna Shoal. As elsewhere, most of the gray whales seen in the north-central Chukchi Sea were associated with mud plumes, which indicate foraging on benthic invertebrates (Nerini 1984). Although Hanna Shoal has not been sampled for potential gray whale prey, the occurrence of feeding whales there and not elsewhere in the northern Chukchi Sea indicate that these waters represent a feeding area that the whales move into when receding ice cover permits.

The highest gray whale relative abundance in the Chukchi Sea was calculated for block 23 (WPUE = 11 .23) and block 22 (WPUE =5.19), with lesser indices calculated for blocks 13 (WPUE = 1.17), 14 (WPUE = 0.68) and 14N (WPUE = 0.62; Table 22). Semi-monthly WPUE values were highest in blocks 13 (WPUE =2.55), 14 (WPUE = 1.45) and 14N (WPUE = 1.23) during the latter half of September; in block 22 (WPUE = 2.17) in early October, and in blocks 22 (WPUE = 10.36) and 23 (WPUE = 22.73) in the latter half of October. Overall, relative abundance was higher in late September (WPUE = 1.03) than in early October (WPUE = 0.39). The somewhat higher overall relative abundance in late October (WPUE = 0.67) was strongly influenced by the aggregation of feeding whales seen in blocks 22 and 23 in 1989 (Moore and Clarke 1990).

Gray whale relative abundance decreased in northern blocks(12, 13, 14, 14N) and increased in southern blocks (22, 23) in the latter half of October. These temporal changes in abundance indices suggest that gray whales probably begin their fall migration from Chukchi Sea by mid-October. Comparisons of gray whale and bowhead whale relative abundance (Tables 16 and 22) indicate there is little spatial or temporal overlap of the two species in the Chukchi Sea study area. Comparisons of bowhead and gray whale temporal abundance indices for 1982-84 indicate that most gray whales migrate out of the northern Chukchi Sea by October as bowhead whales begin migrating into the area (Moore et al. 1986a).

Migration Timing

Gray whales occur in the northeastern Chukchi Sea from July through October {Clarke et al. 1989). Maher (1960) reported that gray whales were considered common along shore between Barrow and Icy Cape by late June or early July. Gray whales probably migrate northward through the Bering Strait and along the northwest coast of Alaska as sea ice recedes in June. By July, whales are seen as far north as Barrow, with distribution extending westward to waters overlying Hanna Shoal sometime between August and September. Gray whales begin to migrate southward from northern Chukchi waters at least by mid-October, as evidenced by the aforementioned decrease in semi-monthly abundance indices in the northern survey blocks. Maher (1960) reported gray

Table 22, Gray whale relative abundance (WPUE = no. whales/survey hour) by survey block, 1982-91.

1982

	16-30 Sept			7-15 Ott			16-31 Ott			1-7 Nov			Total		
Block	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE
12	4.58	0	0.00	5.85	0	0	2.18	0	0	0.00	·	-	12.61	0	0
12N	0.00	-	"	0.07	0	0	0.07	0	0	0.00		·	0.14	0	-
13	1.48	18	12.16	3.58	3	0,84	0.76	0	0	0.00	·	·	5.82	21	3.60
14	0.00	-	-	1.93	0	0	0.48	0	0	0.00	·	-	2.41	0	0
15	0.00	-	-	0.12	0	0	0.00	-	-	0.00		·	0.12	0	0
17	0.00	"	-	3.86	3	0.78	0.00	-	-	0.00			3.86	3	0.78
18	0.00	-	-	1.97	0	0	0.00	-	-	0.00			1.97	0	0
20	0.00	-	-	3.42	2	0.58	0.00	-	-	0.00	·		3.42	2	0.58
21	0.00	-	-	1.35	0	0	0.00	-	-	0.00		·	1.35	0	0
Total	6.06	18	2.97	22.15	8	0.36	3.49	0	0	0.00			31.70	26	0.82

1983

	16-30 Sept			1-15 Ott			16-31 Oct			1-7 Nov			Total		
Block	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE
12	7.89	0	0	8.23	0	O	2.45	0	0	0.00			18.57	0	0
12N	0.26	0	0	0.61	0	0	0.11	0	0	0.00			0.99	0	0
13	3.29	2	0.61	5.14	0	0	3.74	0	0	0.00	-		12.17	2	0.16
13N	0.00			0.24	0	0	0.09	0	0	0.00			0.33	0	0
14	0.87	0	0	2.07	0	0	1.90	0	0	0.00	-		4.84	0	0
15	0.00	·		3.28	0	0	0.39	0	0	0.00	·		3.67	0	0
15N	0.00	·	·	0.56	0	0	0.00			0.00			0.56	0	0
17	0.96	0	0	3.85	0	0	0,47	0	0	0.00			5.28	0	0
18	0.00	·		1.51	0	0	3.08	0	0	0.00			4.59	0	0
19	0.00	·	·	0.32	0	0	0.04	0	0	0.00			0.36	0	0
20	0.00	·	·	0.76	3	3.95	2.23	0	0	0.00			2.99	3	1,00
21	0.00			0.36	0	0	1.36	0	0	0.00			1.73	0	0
22	0.00			3.22	7	2.17	0,38	0	0	0.00			3.60	7	1.94
23	0.00			0.23	0	0	0.36	0	0	0.00			0.59	0	0
24	0.00			0.00		-	0.34	0	0	0.00			0.34	0	0
25	0.00			0.00		-	0.51	0	0	0.00			0.51	0	0
28	0.00	·		0.00		-	0.18	0	0	0.00	·		0.18	0	0
30	0.00			0.85	0	0	0.00			0.00			0.85	0	0
Total	13.27	2	0.15	31.23	10	0.32	17.63	0	0	0.00			62.13	12	0.18

1984

	16-30 Sept			1-15 Ott			16-31 Ott			1-7 Nov			Total		
Block	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE
12	5.64	0	0	7.63	0	0	7,97	0	0	0.00		-	21.24	0	0
12N	0.09	0	0	0.30	0	0	0.12	0	0	0.00	·		0.51	0	0
13	4.77	68	14.26	3.14	12	3.82	2.63	0	0	0.00			10.54	80	7.59
13N	0.02	0	0	0.03	0	0	0.20	0	0	0.00			0.25	0	0
14	2.79	0	0	0.11	0	0	0,00	·	-	0.00	·		2.90	0	0
14N	0.02	0	0	0.00		-	0.00		-	0.00			0.02	0	0
17	0.75	2	2.67	1.90	0	0	0.00		-	0.00			2.65	2	0.75
Total	14.08	70	4.97	13.11	12	0.92	10.92	0	0	0.00			38.11	82	2.15

Table 22 (contd).

	1985														
	16-30 Sept			1-15 Ott			16-31 Ott			1-7 Nov			Total		
Block	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE
12	3.09	0	0	6.08	0	0	7.18	0	0	0.00	-	-	16.35	0	0
12N	0.06	0	0	0.63	0	0	0.02	-	-	0.00	-	-	0.71	0	0
13	0.00	.	-	2.79	0	0	3.62	0	0	0.00	-	-	6.41	0	0
14	0.00	.		2.04	0	0	0.00	-	-	0.00	-	-	2.04	0	0
15	0.00			1.03	0	0	0.00	-	-	0.00	-	-	1.03	0	0
17	0.00	-	.	2.59	0	0	0.00	-	-	0.00	-		2.59	0	0
18	0.00	.	-	2.90	0	0	0.00	-	-	0.00	-	-	2.90	0	0
20	0.00		-	0.10	0	0	0.00	-	-	0.00	-	-	0.10	0	0
Total	3.15	0	0	18.16	0	0	10.82	0	0	0.00	-	-	32.13	0	0

	1986														
	16-30 Sept			1-15 Ott			16-31 Ott			1-7 Nov			Total		
Block	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE
12	3.33	7	2.10	8.34	3	0.36	3.78	0	0	0.00	-	-	15.45	10	0.65
12N	0.10	0	0	1.33	0	0	0,11	0	0	0.00	-		1.54	0	0
13	11.15	10	0.90	9.11	1	0.11	6.60	5	0.76	0.00	-	-	26.86	16	0.60
13N	0.52	0	0	1,80	0	0	0.00	-	-	0.00	-	-	2.32	0	0
14	4.50	12	2.67	7.31	12	1.64	0.62	0	0	0.00	-	-	12.44	24	1.93
14N	0.06	0	0	0.15	0	0	0.00	-	-	0.00	-		0.21	0	0
15	2.74	0	0	0.20	0	0	0.19	0	0	0.00	-	-	3.13	0	0
17	3.75	0	0	3.92	1	0.26	3.42	1	0.29	0.00	-	-	11.09	2	0.18
18	1,01	0	0	2.17	3	1.38	0.53	0	0	0.00	-	-	3.71	3	0.81
20	1.59	0	0	0.00			005	0	0	0.00	-		1.64	0	0
22	0.80	0	0	0.00			0.00	-	-	0.00	-	-	0.80	0	0
Total	29.55	29	0.98	34.33	20	0.58	15.30	6	0.39	0.00	-	-	79.18	55	0.69

	1987														
	16-30 Sept			1-15 Ott			16-31 Oct			1-7 Nov			Total		
Block	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE
12	7.72	0	0	7.11	0	0	8.11	0	0	0.00	-	-	22.94	0	0
12N	2.74	0	0	3.35	0	0	4.14	0	0	0.00	-	-	10.23	0	0
13	10.96	9	0.82	8.04	19	2,36	4.85	7	1.44	0.00	-	-	23.85	35	1.47
13N	1.73	0	0	1,09	0	0	2.38	0	0	0.00	-		5.20	0	0
14	5.31	4	0.75	2.62	0	0	0.03	-	-	0.00	-		7.96	4	0.50
15	3.44	0	0	0.00			0.00	-	-	0.00	-		3.44	0	0
16	0.41	0	0	0.00			0.00	-	-	0.00	-		0.41	0	0
17	2.60	0	0	0.95			2.88	0	0	0.00	-	-	6.43	0	0
18	2.86	0	0	0.00			0.54	0	0	0.00	-	-	3.40	0	0
20	1.68	0	0	0.00			0.00	-	-	0.00	-	-	1.68	0	0
22	2.34	10	4.27	0.00			0.00	-	-	0.00	-		2.34	10	4.27
Total	41.79	23	0.55	23.16	19	0.82	22.93	7	0.31	0.00	-	-	87.88	49	0.56

Table 22 (contd).

1988

Block	16-30 Sept Hrs	GW	WPUE	1-15 Ott Hrs	GW	WPUE	16-31 Ott Hrs	GW	WPUE	1-7 Nov Hrs	GW	WPUE	Total Hrs	GW	WPUE
12	0.00		-	2.79	0	0	0.19	3	15.79	0.00	-	-	2.98	3	1.01
12N	0.00	·	-	3.06	0	0	0.00	·	-	0.00	·	-	3.06	0	0
13	0.00	·	-	8.86	0	0	1.12	0	0	0.00	·	-	9.98	0	0
13N	0.00		-	3.58	0	0	0.00	0	0	0.00		-	3.58	0	0
14	0.00	·	-	5.11	0	0	0.16	0	0	0.00	·	-	5.27	0	0
14N	0.00	·	-	2.76	0	0	0.00	-	-	0.00		-	2.76	0	0
15	0.00	·	-	3,67	0	0	0.00	·	-	0.00	·	-	3.67	0	0
15N	0.00	·	-	3.62	0	0	0.00	·	-	0.00	·	-	3.62	0	0
16	0.00	·	-	3.21	0	0	0.00	·	-	0.00	-	-	3.21	0	0
16N	0.00	·	-	3.89	0	0	0.00	-	-	0.00	·	-	3.89	0	0
17	0.00	-	-	2.41	0	0	1.36	0	0	0.00		-	3,77	0	0
18	0.00	·		4.13	0	0	1.18	0	0	0.00		-	5.31	0	0
19	0.00		-	0.86	0	0	0.00	·	-	0.00		-	0.86	0	0
20	0.00	·	-	0.04	0	0	0.00		-	0.00		-	0.04	0	0
Total	0.00	·	-	47.99	0	0	4.01	3	0.75	0.00		-	52.00	3	0.06

1989

Block	16-30 Sept Hrs	GW	WPUE	1-15 Ott Hrs	GW	WPUE	16-31 Ott Hrs	GW	WPUE	1-7 Nov Hrs	GW	WPUE	Total Hrs	GW	WPUE
12	5.47	0	0	4.29	0	O	1.18	0	0	0.00		-	10.94	0	0
12N	4.70	0	0	0.00		-	0.00	-		0.00			4.70	0	0
13	7.82	9	1.15	6.51	13	2.00	12.88	0	0	0.00		-	27.21	22	0.81
13N	3.44	0	0	0.92	0	0	3.23	0	0	0.00			7.59	0	0
14	3.18	8	2.52	6.86	7	1.02	4.39	0	0	0.00		-	14.43	15	1,04
14N	3.73	7	1.88	3.39	7	2.06	0.41	0	0	0.00		-	7.54	14	1.86
15	2.12	0	0	2.20	0	0	4.03	0	0	0.00		-	8.35	0	0
15N	3.91	0	0	2.98	0	0	3.74	0	0	0.00	·	-	10.63	0	0
?6	0.39	0	0	0.00		-	3,40	0	0	0.00	·	-	3.79	0	0
16N	3.01	0	0	0.00		-	0.05	-	-	0.00		-	3.06	0	0
17	0.00	·	-	3.06	0	0	2.79	0	0	0.00		-	5.85	0	0
18	0.68	0	0	0.02		-	5.85	0	0	0.00		-	6.55	0	0
20	0.00	-	-	0.00	·	-	2.30	0	0	0.00		-	2.30	0	0
21	0.00		-	0.00		-	0.24	0	0	0.00	·	-	0.24	0	0
22	0.00		-	0.00			4.83	54	11.18	0.00			4.83	54	11.18
23	0.00		-	0.00		-	2.50	65	26.00	1.11	0	0	3.61	65	18.00
24	0.00		-	0.00		-	0.00	-		4.04	0	0	4.04	0	0
25	0.00		-	0.00		-	0.00	-		1.32	0	0	1.32	0	0
30	0.00		-	0.00	-		1,97	0	0	0.77	0	0	2.74	0	0
31	0.00		-	0.00	·	-	0.47	0	0	3.68	0	0	4.15	0	0
Total	38.46	24	0.62	30.23	27	0.89	54.26	119	2.19	10.92	0	0	133.87	170	1.27

Table 22 (contd).

Block	16-30 Sept Hrs	GW	WPUE	1-15 Ott Hrs	GW	WPUE	16-31 Ott Hrs	GW	WPUE	1-7 Nov Hrs	GW	WPUE	Total Hrs	GW	WPUE
1990															
12	0.00	-	-	7.08	0	O	2.32	0	0	1.09	0	0	10.49	0	o
12N	0.00	.	-	1.33	0	0	2.69	0	0	2.80	0	0	6.82	0	0
13	0.00			2.11	1	0.47	3.83	0	0	2.37	0	0	8.31	1	0.12
13N	0.00		-	0.94	0	0	3.31	0	0	1.14	0	0	5.39	0	0
14	0.00	.	-	0.00	.	-	3.14	0	0	0.64	0	0	3.78	0	0
14N	0.00	-	-	3.40	0	0	2.29	0	0	1.00	0	0	6.69	0	0
15	0.00	.	-	0.00	.		1.80	0	0	0.19	0	0	1.99	0	0
15N	0.00	-	-	0.00	.	-	2.60	0	0	0.00		-	2.60	0	0
16	0.00	.	-	0.00	-	-	0.15	0	0	0.00		-	0.15	0	0
16N	0,00	-	-	0.00	-	-	0.20	0	0	0.00		-	0.20	0	0
18	0.00	-		0,00			0.02	0	0	0.56	0	0	0.58	0	0
20	0.00			0,00		-	0.00			0.15	0	0	0.15	0	0
21	0.00		-	0.00		-	0.00			0.70	0	0	0,70	0	0
22	0.00	.		0.00		-	0.00			0.80	0	0	0.80	0	0
23	0.00	.	-	0.00		-	0.00			1.12	0	0	1.12	0	0
24	0.00		-	0.00		-	0.00			0.13	0	0	0.13	0	0
30	0.00		-	0.00		-	0.00			3.87	0	0	3.87	0	0
31	0.00		-	0.00		-	0.00			2.31	0	0	2.31	0	0
Total	0.00		-	14.86	1	0.07	22.35	0	0	18.87	0	0	56.08	1	0.02

Block	16-30 Sept Hrs	GW	WPUE	1-15 Ott Hrs	GW	WPUE	16-31 Ott Hrs	GW	WPUE	1-7 Nov Hrs	GW	WPUE	Total Hrs	GW	WPUE
1991															
12	5.82	1	0.17	8.07	1	0.12	5.36	0	o	0.00		-	19.25	2	0.10
12N	1.61	0	0	2.52	0	0	5.00	0	0	0.00		-	9.13	0	0
13	7.26	3	0.41	11.70	7	0.60	9.23	0	0	0.36	o	0	28.55	10	0.35
13N	3.13	1	0.32	5.30	0	0	0.29	0	0	0.00	-	-	8.72	1	0.11
14	1.96	3	1.53	5.97	0	0	4.03	0	0	0.09	0	0	12.05	3	0.25
14N	1.83	0	0	4.87	1	0.21	0.11	0	0	0.00		“	6,81	1	0.51
15	0.00			4.83	0	0	1.07	0	0	0.00		-	5.90	0	0
15N	0.00			1.90	0	0	2.61	0	0	0.00			4.51	0	0
16	0.00		-	0.17	0	0	2.93	0	0	0.00		-	3.10	0	0
16N	0.00		-	3.10	0	0	0.16	0	0	0.00		-	3.26	0	0
17	0.00			2.96	9	3.04	3.46	0	0	0.27	0	0	6.69	9	1.35
18	0.00			5.23	0	0	2.65	0	0	0.38	0	0	8.26	0	0
19	0.00			0.00			1.51	0	0	0.72	0	0	2.23	0	0
20	0.00		-	0.07	0	0	2.93	0	0	0.00	0	0	3.00	0	0
21	0.00			0.00			0.00			1.38	0	0	1.38	0	0
22	0.56	0	0	0.00			0.00		-	0.77	0	0	1.33	0	0
23	0.00			0.00			0.00			0.48	0	0	0.48	0	0
24	0.00		-	0.00			0.00		-	0.87	0	0	0.87	0	0
25	0.00	-		0.00			0.00			0.67	0	0	0.67	0	0
30	0.87	0	0	0.00			0.00		-	3.57	0	0	4.44	0	0
31	0.00		-	0.00	-		0.00		-	2.58	0	0	2.58	0	0
Total	23.04	8	0.35	56.69	18	0.32	41.34	0	0	12.14	0	0	133.21	26	0.20

Table 22 (contd).

CUMULATIVE 1982-91

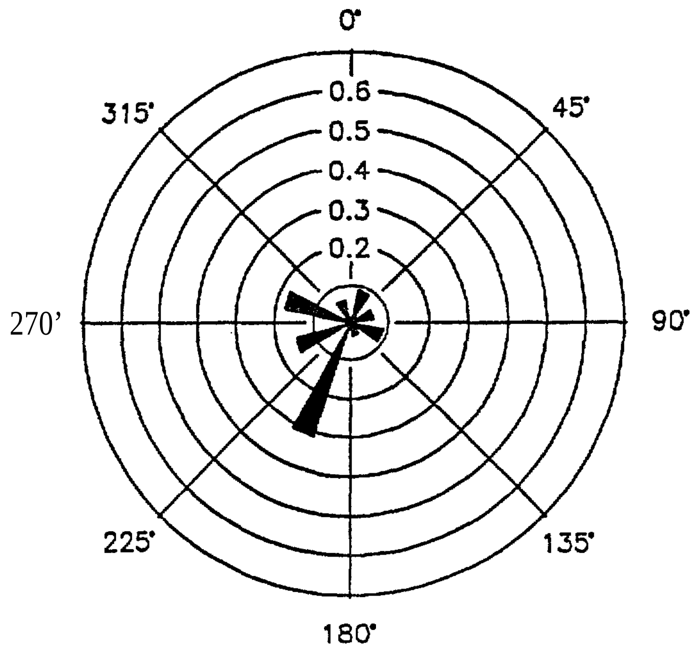
	16-30 Sept			1-15 Ott			16-31 Ott			1-7 Nov			Total		
Block	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE	Hrs	GW	WPUE
12	43.54	8	0.18	65.47	4	0.06	40.71	3	0.07	1.10	o	0	150.82	15	0.10
12N	9.57	0	0	13.22	0	0	12.27	0	0	2.80	0	0	37.86	0	0
13	46.73	119	2.55	60.97	56	0.92	49.26	12	0.24	2.73	0	0	159.69	187	1.17
13N	%.85	1	0.11	13,91	0	0	9.50	0	0	1.14	0	0	33.40	1	0.03
14	18.62	27	1.45	34.03	19	0.56	14.74	0	0	0.73	0	0	68.12	46	0.68
14N	5.67	7	1.23	14.61	8	0.55	2.82	0	0	1.00	0	0	24.10	15	0.62
15	8.30	0	0	15.34	0	0	7.48	0	0	0.19	0	0	31.31	0	0
15N	3.98	0	0	9.06	0	0	8.95	0	0	0.00			21.99	0	0
16	0.79	0	0	3.38	0	0	6.47	0	0	0.00			10.64	0	0
16N	3.01	0	0	6.99	0	0	0.41	0	0	0.00			10.41	0	0
17	8.05	2	0.25	25.50	13	0.51	14.38	1	0.07	0.27	0	0	48.20	16	0.33
18	4.56	0	0	17.92	3	0.17	13.83	0	0	0.94	0	0	37.25	3	0.08
19	0.00			1.19	0	0	1.54	0	0	0.72	0	0	3.45	0	0
20	3.27	0	0	4,40	5	1.14	7,50	0	0	0.15	0	0	15.32	5	0.33
21	0.00	·		1.71	0	0	1.60	0	0	2.08	0	0	5.39	0	0
22	3,70	10	0.03	3.22	7	2.17	5.21	54	10.36	1.56	0	0	13.69	71	5.19
23	0.00	-		0.23	0	0	2.86	65	22.73	2.70	0	0	5.79	65	11.23
24	0.00		-	0.00			0.34	0	0	5.03	0	0	5.37	0	0
25	0.00			0.00	-		0.51	0	0	1.99	0	0	2.50	0	0
28	0.00			0.00			0.18	0	0	0.16	0	0	0.34	0	0
30	0.87	0	0	0.85	·		1.97	0	0	8.20	0	0	11.89	0	0
31	0.00	·	-	0	0	0	0.47	0	0	8.56	0	0	9.03	0	0
Total	169.51	174	1.03	292.00	115	0,39	203.00	135	0.67	42.05	0	0	706.56	424	0.60

whales moving southwest along the Alaskan coast near Barrow by early August. The timing of their departure from the area probably varies as a result of annual differences in prey availability and environmental conditions.

The migration route of gray whales in the study area is poorly understood. Gray whale swimming direction was significantly clustered about a southwesterly heading (239 °T, $p < 0.05$), although the cell with the greatest number of occurrences indicated southerly (181 -225 °T) swimming directions were commonly observed (Fig. 30). The nearshore distribution of gray whales in early October suggests that some whales may migrate along the coast, as in other parts of their range (Swartz 1986; Poole 1984). Gray whales occur along the coast between Kotzebue and Point Hope in July, and may use the shallow coastal areas as calf-weaning areas (Moore et al. 1986b), as reported for the Chukchi coastline (Bogoslovskaya 1986). The route taken by gray whales seen offshore in the north-central Chukchi Sea is unknown. Whales may swim south-southwest past Cape Lisburne into the south-central Chukchi Sea, or perhaps take a more southwesterly route to the Chukchi peninsula. The migration route through the southern Chukchi Sea is similarly ill-defined. Presumably, gray whales continue to use both coastal and offshore waters during the southward migration, taking advantage of localized prey availability along the way.

Calf Sightings

A gray whale calf seen on 22 September 1989 was the only calf seen in the study area from the latter half of September through early November. From 1982-87, only two gray whale calves were seen in the Chukchi Sea in early September, and one in August, with all others (89%, n =33) seen in July (Clarke et al. 1989). Gray whale calves may not occur in the study area in fall because they are weaned in summer and migrate out of the area. Bogoslovskaya (1986) reported that calves are weaned in July and August and assemble in localized areas along the Chukchi peninsula. Calves were found in significantly higher ratios along the northeastern Chukchi coast than in the northern Bering Sea in July (Moore et al. 1986 b). Conversely, newly weaned calves may not be positively identified as "calves" when not accompanied by an adult. Obtaining absolute n = 32



a = 239-T, r = 0.31
z = 3.12, $p < 0.05$

Figure 30. Cumulative (1982-91) gray whale swimming direction in the study area.

whale sizes from an aircraft not equipped for photogrammetry is impossible. Further, estimates of gray whale calf length at weaning and at one year are quite variable (Sumich 1986).

Behavior

Feeding was the behavior noted most often (84%, n =358) for gray whales, as evidenced by conspicuous mud plumes (Fig. 31). Grays were also seen swimming (13Y0, n =57), diving (0.5%, n = 1), as part of a cow-calf association (0.5%, n = 2) and resting (1%, n=6). Feeding opportunities in the northern Chukchi Sea likely influence gray whale distribution and abundance. Whales may forage along the coast as they migrate into the Chukchi Sea in July and August, then move to shallow offshore areas overlying shoals, such as Hanna Shoal in the north-central Chukchi Sea, in September and October to forage on additional rich feeding areas exposed by receding ice (Clarke et al. 1989). Gray whale benthic feeding traces have been identified by Phillips (1987) from south of Icy Cape to north of Point Franklin, especially at depths between 23 and 24 m. Prey communities in the Chukchi Sea are generally less dense but composed of a greater

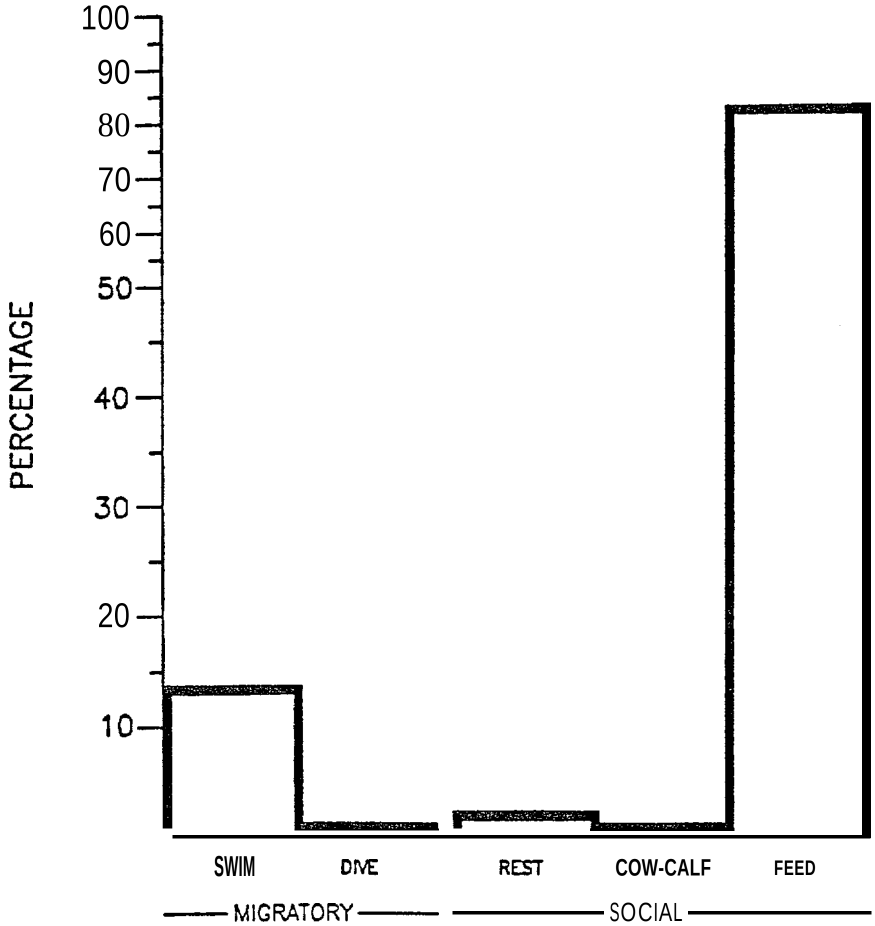


Figure 31. Summary of gray whale behavior, 1982-91.

variety of species than those in the Bering Sea, and include preferred prey species such as amphipods of the genera Ampelisca, Anonyx and Pontoporeia (Gill and Hall 1983; Nerini and Oliver 1983; Oliver et al. 1983; Nerini 1984; Stoker in press).

Gray whale foraging may play an important role in structuring the benthic community (Nerini and Oliver 1983) and thereby affect inter-annual variation in gray whale distribution and relative abundance. Patterns of infaunal community composition were correlated with the size and age of feeding pits created by gray whales in the northern Bering Sea. Abundance of the dominant prey species, Ampelisca macrocephala, was depressed in high-pit areas, implying that the same areas could not support as many gray whales year after year. This may account for some of the variability in gray whale abundance in survey blocks 13 and 14, For example, relatively high gray whale abundance was calculated for block 13 in 1982, 1984, and 1987, with low indices there in alternate years 1983, 1985-86 and 1988-91 (see Table 22). Similarly, abundance in block 14 was relatively high in 1986 and 1989, but not in 1987, 1988 or 1990-91. Oscillations in survey block relative abundance support the suggestion that whale foraging influences the benthic communities on which the whales feed, thereby affecting annual variation in whale distribution and abundance.

Habitat Relationships

Gray whales were usually seen in water ≥37 m (n= 270, 64%), either offshore in waters bordering Hanna Shoal or south of Point Hope in the south-central Chukchi Sea. Mean depth at gray whale sightings was 34.1 m (range 4-91 m). The mean depth (30.8 m} at gray whale sightings in the northeastern Chukchi Sea (north of700 N) was significantly shallower than that (43.7 m) in the south-central Chukchi Sea (south of 70° N; t= 4.45, p < 0.001). The propensity for gray whales to occur in coastal or shoal-waters (i.e. depth c37 m) was tested by comparing the proportion of rSI gray whales in water <37 m to the proportion of <37 m habitat available (11'?40) in the northeastern Chukchi Sea (north of 70° N, west of 157" W). The proportion of gray whales (30%) in water <37 m was significantly higher than that expected (χ^2 = 47.5, p c 0.001), indicating a strong preference for the shallower areas. The relatively shallow shoals seem to support adequate gray whale prey communities to make them important offshore feeding habitat. In the south-central Chukchi Sea (67-700 N, 163-1690 W), however, the percentage of rSI gray whales (16%) in water <37 m was significantly less than that expected based on the proportion (43%) of available habitat c37 m deep (χ^2 = 42.9, p < 0.001).

Gray whales were usually seen (93%, n =394) in open water (0-10% ice cover); nine whales (2.5%) were seen in 11-40 percent ice cover, and 21 whales (4.5%) were seen in 71-99 percent ice cover. Significantly more rSI gray whales than expected were observed in open water years (log-likelihood G =97.40, p <0.001). Although gray whales seem to prefer ice-free water, whales in ice often continue to feed. Fifteen gray whales were seen feeding in 71-90 percent ice cover.

Other Marine Mammals

Belukha

There were 487 sightings for a total of 3,972 belukhas in the study area from mid-September through October 1982-91 (Fig. 32). Belukha distribution was relatively nearshore in the western Beaufort Sea, but dispersed west of Point Barrow, with whales seen as far north as about 740 N, 161 °50’W and as far south as about 69030’N, 167 °35’W during fall. Over half of the total number of whales (51%, n =2,024) were seen in two of the heavy-ice years (1983, 1988) over the ten-year period.

Relative abundance and migration patterns for belukha stocks are poorly understood. Belukhas seen in the northeastern Chukchi Sea in fall are probably part of the Beaufort Sea/Mackenzie Delta stock, which is estimated to contain 11,500 animals (IWC, 1992 b). Two additional stocks are also present in the northeastern Chukchi Sea particularly during summer: the eastern Chukchi stock is estimated at 2,500-3,000 animals (IWC 1992b), while estimates of belukhas summering in the western Chukchi Sea offshore of the Chukchi Peninsula range from 2,000 to 8,000 animals (Hazard 1988). Each of these stocks, as well as several others, winter mainly in the Bering Sea. The degree of mixing between these several stocks is unknown.

Highest belukha abundance was calculated for block 16N and block 12 (Table 23). Relative abundance in survey blocks 14N, 15N and 16N was three to eight times higher than in blocks 14, 15, and 16, indicating that more belukhas occur in the northern waters of the study area than in waters farther south. Low abundance indices in central and southern Chukchi Sea survey blocks may be due to the timing of surveys relative to the belukha migration. The belukha migration west from the Canadian Beaufort Sea begins about mid-August (Harwood and Ford 1983; Norton and Harwood 1985), with the peak of the fall migration through the western Alaskan Beaufort Sea (150-1570 W) in late September (Clarke and Moore 1989). Substantial numbers of belukhas may not pass through the southern Chukchi Sea until late October or early November, when surveys have either been directed toward the Hope Basin area or completed.

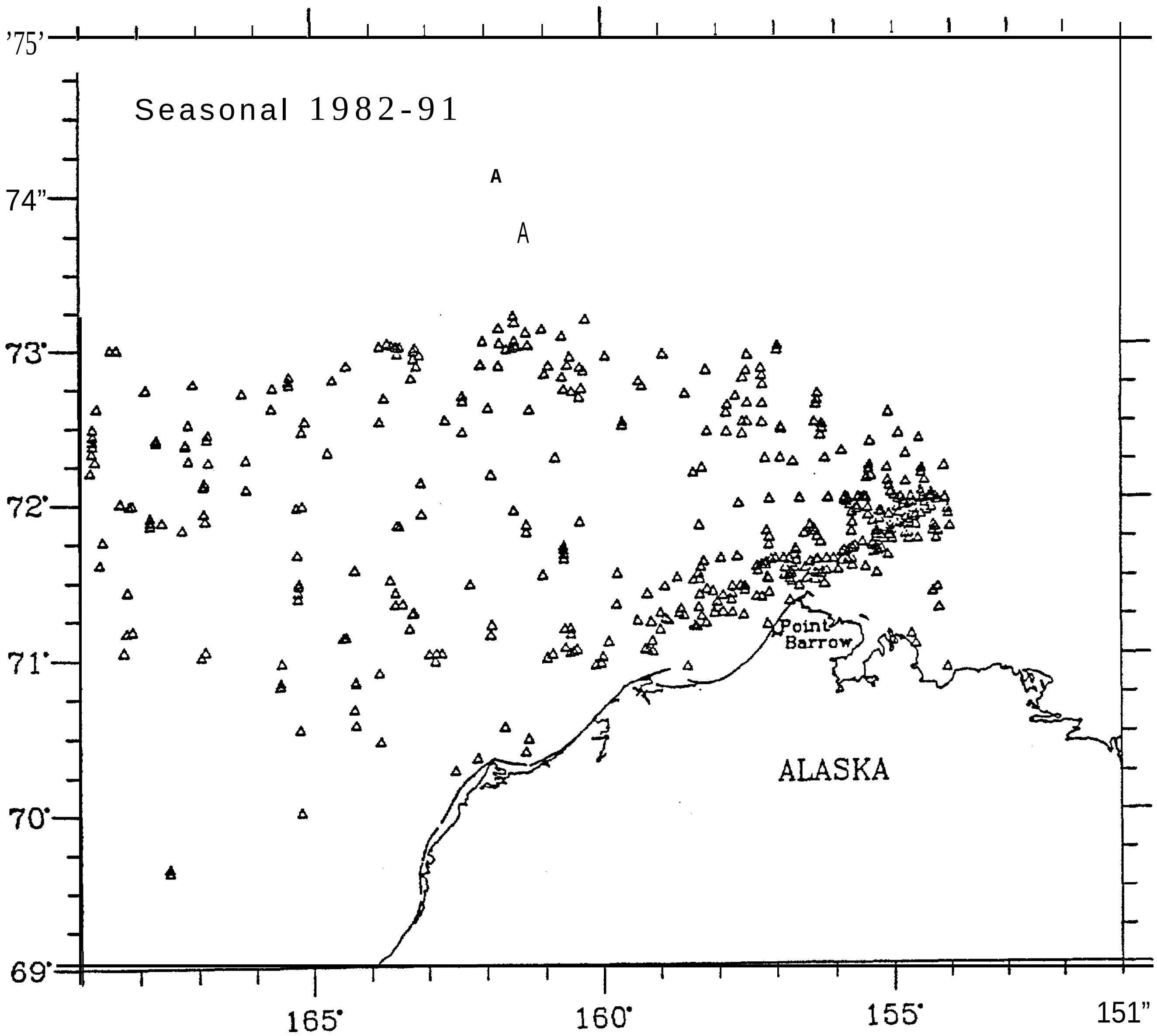


Figure 32. Cumulative (1982-91) distribution of 487 sightings for a total of 3,972 belukhas.

Table 23. Belukha relative abundance (WPUE = no. whales/survey hour) by survey block, **1982-91.**

Block	Hours	No. Belukhas	WPUE
12	150,82	1530	10.14
12N	37.86	194	5.12
13	159.69	1299	8.13
13N	33.40	165	4.94
14	68.12	114	1.67
14N	24.10	139	5.77
15	31.31	45	1.44
15N	21.99	97	4.41
16	10.64	33	3.10
16N	10.41	255	24.50
17	48.20	17	0.35
18	37.25	33	0.89
20	15.32	1	0.07
21	5.39	7	1.30

Belukha fall migration timing and route in the Chukchi Sea are not well defined. Swimming direction was significantly clustered about 252 'T ($p < 0.001$) in the western Beaufort Sea and about 249 "T ($p < 0.001$) in the Chukchi Sea (Fig. 33); these data sets were not significantly different (Watson $U^2 = 0.105$, $p < 0.50$). The relatively high abundance indices in blocks 14 N-16N suggest that some belukhas may swim across the northern Chukchi Sea towards Herald and Wrangel islands before swimming south along the Chukchi coast. Large numbers of belukhas were observed north, and within 80 miles, of Wrangel Island (70045'N, 177" W) on 4 and 17 October 1960 (Kleinenberg et al. 1964). The first observation was of a 15 km (in length) aggregation of whales in small groups migrating east (sic) toward the Bering Strait. The second report was of a group of 300-350 belukhas, also moving towards the Bering Strait. Belukhas seen near Wrangel Island could also be whales that summered there.

The average depth at belukha sightings in the Beaufort Sea (301.6 m) was significantly deeper ($t = 7.26$, $p < 0.001$) than that in the Chukchi Sea (81.8 m). This is

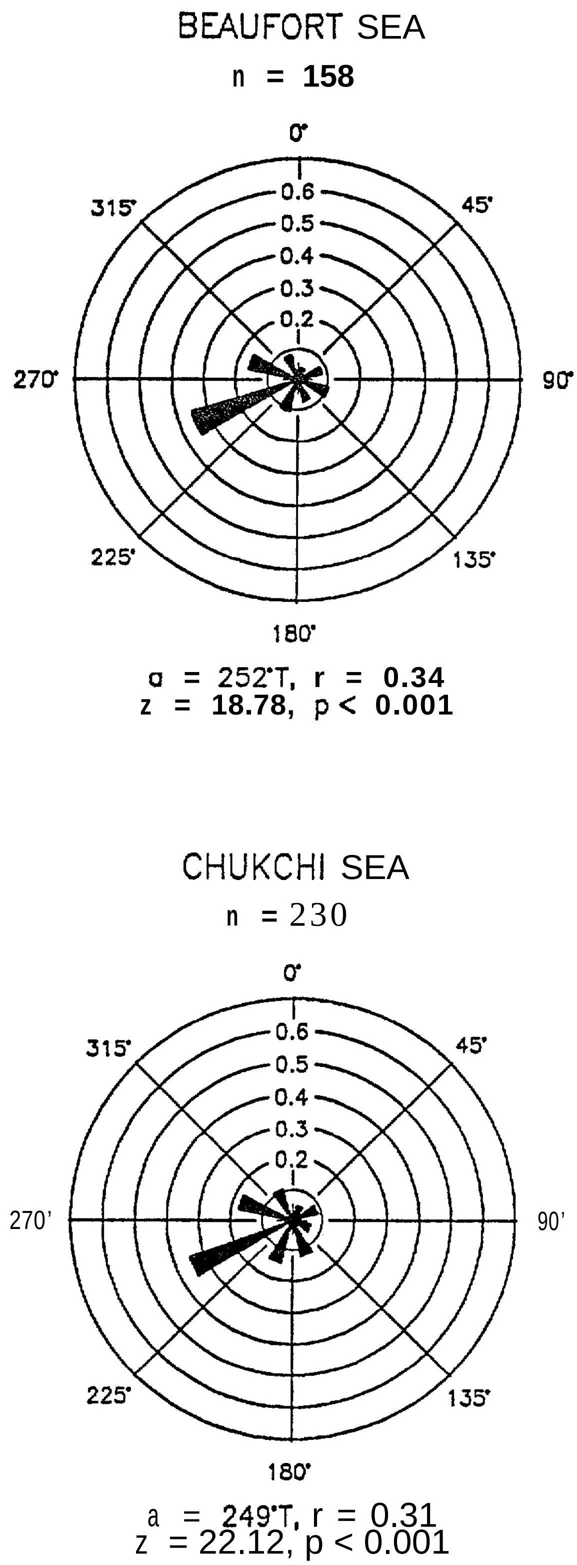


Figure 33. Cumulative (1982-91) belukha swimming direction in the western Beaufort and northeastern Chukchi seas.

probably not due so much to habitat preference as to differences in depths in the two regions. The overwhelming majority (n= 3,879, 99%) of belukhas in both regions were seen in water ≥37 m deep. A significantly greater percentage (97%) of rSI belukhas were seen in water ≥37 m deep than expected in the northeastern Chukchi Sea based on the percentage of available habitat (x^2=105.7, $p < 0.001$).

Most belukhas (64%) were seen in heavy (71 -99%) ice conditions. Twenty-three percent were seen in open water, eight percent were in light (11 -40%) ice conditions, and five percent were in moderate (41-70%) ice conditions. The relationship between belukha distribution and ice cover is not clear. More rSI belukhas than expected, based on survey effort, were seen during heavy-ice years in both the Beaufort (log-likelihood G =373.0, $p<0.001$) and Chukchi (log-likelihood G =257.9, $p<0.001$) seas. However, rSI belukha WPUE was not correlated with ice condition in either the Beaufort ($r = 0.338$, $p< 0.50$) or Chukchi ($r = 0.392$, $p <0.50$) sea.

Walrus

There were 820 sightings for an estimated 18,878 total of walruses over the ten survey seasons (Table 24). Numbers of walrus resting on floe ice were usually estimated to the nearest 10 animals, so total numbers are imprecise. Significantly more rSI walruses were observed in heavy-ice years than expected based on survey effort (log-likelihood G =2588.1, $p< 0.001$), illustrating the strong association between walrus and the ice edge (Gilbert 1989). However, there was only a weak positive correlation ($r = 0.316$, $p< 0.50$) between rSI walrus WPUE and ice condition.

Polar Bear

There were 155 sightings of 254 polar bears over the ten survey seasons (Table 24). Polar bears were seen on the ice and swimming in the water. Polar bear rSI SR (SR= no bears/t-h survey effort) was positively associated with ice condition, although not statistically so ($r= 0.577$, p c 0.10). Significantly more rSI polar bears were observed during heavy-ice years than expected (log-likelihood G= 15.7, $p<0.001$).

Table 24. Summary of annual survey effort (hours), observed ice conditions (ICE), and sightings (S1), number (No.) and sighting rate (No./h) of walrus and polar bear in the study area, 1982-91.

YEN?	EFFORT (hours)	ICE	WALRUS SI/No.	WALRUS (No./h)	POLAR BEAR SI/No.	POLAR BEAR (No./h)
1982	31.71	no-ice	1 7/457	(14.41)	3/5	(0.16)
1983	61.96	heavy	81 /2379	(38.40)	25/58	(0.94)
1984	38.10	light	16/132	(3.46)	1/2	(0.05)
1985	32.11	heavy	o	(-)	3/5	(0.16)
1986	79,20	no-ice	25/52	(0.66)	7/10	(0.13)
1987	87.85	no-ice	41/1179	(13,42)	3/5	(0.06)
1988	51.90	heavy	92/3786	{72,88)	30/51	(0.98)
1989	133.72	no-ice	125/2001	(14.96)	24/37	(0.28)
1990	85.96	no-ice	178/1319	(15.34)	41/53	(0.62)
1991	133.78	heavy	245/7573	(56.61)	18/28	(0.21)
1982-91	736.34	----	820/18,878	(25,64)	155/254	(0.34)

CONCLUSIONS AND RECOMMENDATIONS

Aerial surveys for endangered bowhead and gray whales have been flown over the Alaskan Chukchi and western Beaufort seas since 1982. Survey effort in the study area varied each year with task priorities. Although there are limitations inherent to aerial surveys, flying remains the best means of sampling large OCS Planning Areas over a short period. An endangered whale sighting data base compiled over several seasons provides an overview to patterns of distribution, relative abundance, and habitat preference necessary for decision-making relative to the leasing and development of the Alaskan OCS. The following is a list of conclusions from the ten-year study and recommendations for future field studies.

Conclusions

1. Bowhead whales occur in the western Beaufort and northeastern Chukchi seas from at least mid-September through the end of October, and likely into November. Bowheads have been seen near Point Barrow in late August and early September in recent years (Moore 1992), suggesting that whales sometimes occur in the study area prior to mid-September. Bowhead distribution is predominantly near shore east of Point Barrow, and dispersed west of Point Barrow.

2. Sighting rates (SR) based on random sighting (rSI) data indicate that bowhead migration timing into the Chukchi Sea begins in mid-September with an early component (SR = 1.43 to 2.02), peaks in early-to mid-October (SR = 1.69 to 3.88), with a few whales migrating through in late October (SR =0.36 to 1.15).

3. Bowheads swim along a westerly course (2720 T, $p< 0.001$) and appear to follow a nearshore migration route in the western Beaufort Sea. Bowhead swimming direction was significantly clustered about a southwesterly heading (248 'T, $p< 0.001$) in the northeastern Chukchi Sea, significantly different (Watson U^2=0.356, $p<0.002$)) from the mean 272 'T heading in the Beaufort Sea.

However, the occurrence of some whales far offshore in the north-central Alaskan Chukchi Sea indicates that either some whales maintain a northwest heading after passing the Point, or enter the study area from the north.

4. There was no significant difference in bowhead whale migration route across the northeastern Chukchi Sea among years 1983, 1988 and 1989, nor among these years and cumulative 1982-91 data, as determined by covariance analysis of lines fit to annual rSI data sets, Sightings northof720 N were poorly accounted for by this method because a sufficient data set for analysis was collected in only one year (1989). The migration corridor south of 70°30'N is ill-defined for lack of sightings.

5. Both swimming direction and linear regression analysis suggest that most bowheads (91% rSI) migrate southwest from Point Barrow (Fig. 34) and do not follow the ice edge across the northern Chukchi Seato Wrangel Island, as postulated by Braham et al. (1984). Some bowheads (9% rSI) probably migrate across the northern Chukchi Sea, but the paucity of whale sightings north of 72°N indicate these whales are in the minority.

6. The bowhead whale migration corridor in the Chukchi Sea may be influenced by current patterns in the basin. Major currents in the Chukchi Sea are bathymetrically channeled between shoals (water depth <37m) with filament branches occurring west of Icy Cape, Peard Bay and Point Barrow, Fronts associated with current interfaces may consolidate prey and provide feeding opportunities for bowheads, or temperature and salinity differences between water masses may provide cues for whales during the fall migration.

7. Bowhead whales feed in coastal waters between Point Barrow and Smith Bay in some, but not all, years. In 1984 and 1989, feeding aggregations numbered ca. 40-70 whales and remained in the same general area for at least 10 days. In contrast, gray whales fed in the study area each year they were observed there.

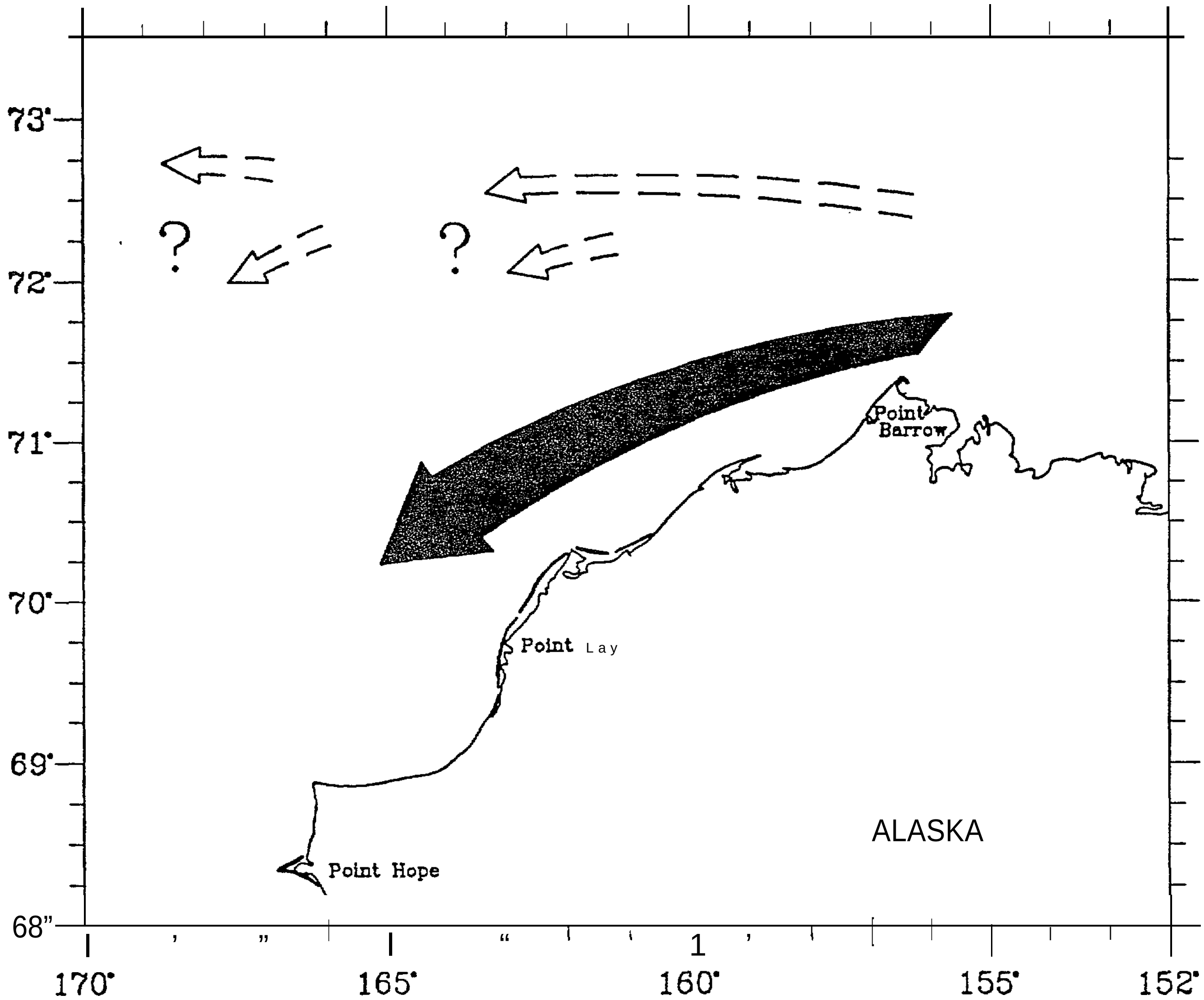


Figure 34. Observed bowhead whale migration route(s) across the northeastern Chukchi Sea, 1982-91,

Although bowhead and gray whale feeding areas occurred near each other near Point Barrow (Fig. 35), differences in prey preference likely precludes competition between the two species.

8. The occurrence of **feeding** whales strongly influences annual relative abundance indices, water depth associations and proportions of behaviors observed. Bowhead sighting rate ranged from 0.40 (1990) to 1.33 (1982) in years when feeding aggregations were not seen in the Beaufort Sea, compared to 8.50 (1984) and 4.79 (1989) for years when feeding whales were seen. The lack of bowhead

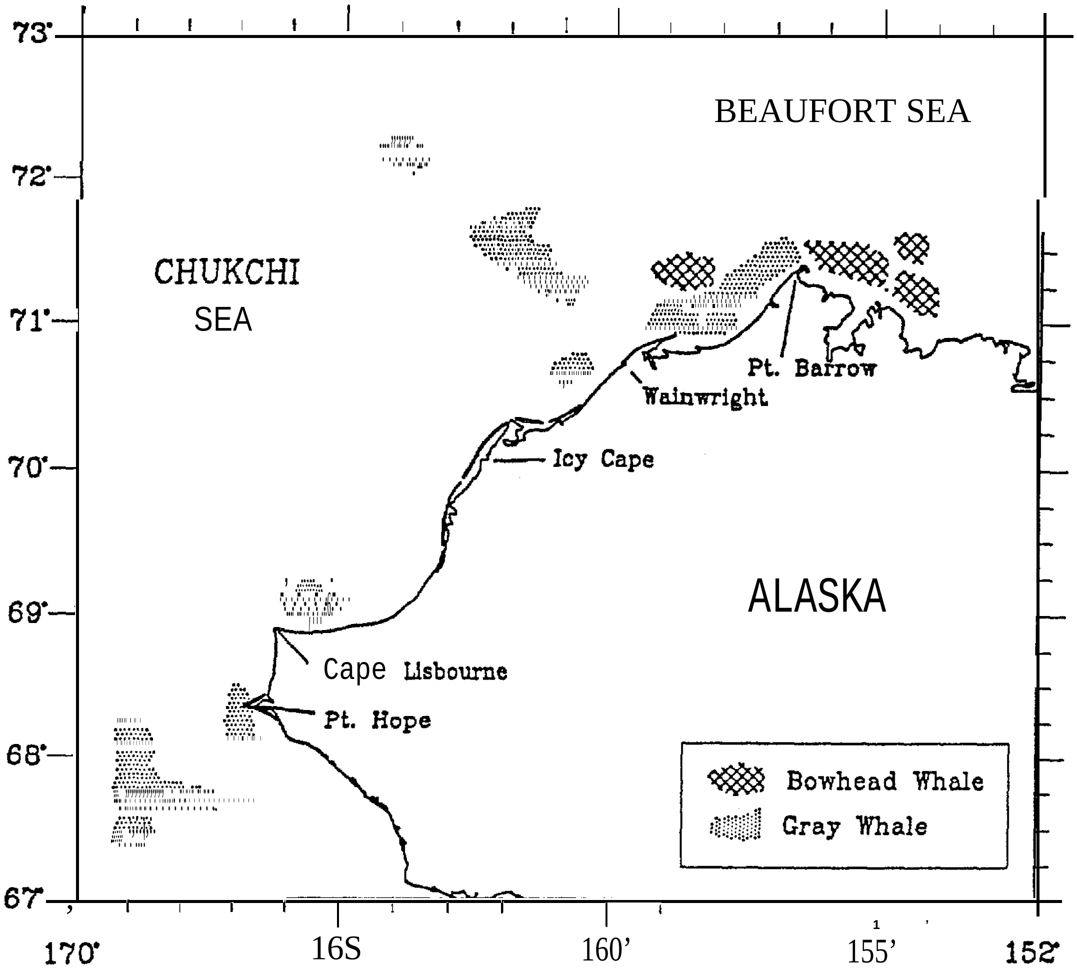


Figure 35. Bowhead whale and gray whale feeding areas in the study area, 1982-91,

whale feeding aggregations in the Chukchi Sea is reflected in the relatively low sighting rates there in all years (range: 0.05-0.69). Similarly, gray whale relative abundance was higher in survey blocks where whales were seen feeding compared to blocks where they were not.

9. Bowhead whale calves were seen in the study area only in October, with no clear evidence of spatial or temporal segregation within the month. Two calves were seen in the company of three adult whales just north of the study area (73001 'N, 161 °02'W) in 1990.

10. With the exception of mating, bowhead whales exhibited all social behaviors described in Wursig et al. (1989). Log-play was observed in 1989 and bouts of breaching and slapping lasting up to 30 minutes were observed in 1989 and 1991.

11. Most bowheads (84%) in the Alaskan Beaufort Sea were in water <37 m deep, due to the influence of feeding whales in shallow nearshore waters in 1984 and 1989. In contrast, most bowheads (80%) in the northeastern Chukchi Sea were in water ≥37 m, despite the fact that the Chukchi Sea is mostly shallow continental shelf. However, the percentage of rSI bowheads in water ≥37 m was not different from that expected based on the available habitat. Most bowheads (66%) were seen in open water (O-10% ice cover), and were not concentrated along the ice edge. Bowheads were seen in whatever ice condition predominated during the survey season each years.

12. Gray whales feed along the Alaskan coast from Point Franklin to Point Barrow and near Cape Lisburne and Point t-lope, about 150-200 km offshore near Hanna Shoal, and in the south-central Chukchi Sea (Hope Basin; Fig. 35). Most gray whales seen in fall are feeding (84%, n = 358) and not migrating, although cumulative (1982-91) swimming direction was southward (2390 T, p< 0.05). An aggregation of about 60 gray whales seen in the south-central Chukchi Sea on 30-31 October 1989 was feeding and not migrating.

13. Only one gray whale calf was seen in the study area, in September 1989, during fall surveys. Calves occur in relatively high ratios along the Chukchi coast in July (Moore et al. 1986b) indicating that the Chukchi Sea maybe an important weaning area. Bogoslovskaya (1986) suggests that gray whales wean calves along the Chukchi coast. As suggested in Clarke et al. (1989), the dearth of calf sightings in the study area in fall may indicate that weaning is nearly complete by then.

14. Most gray whales (64%) were seen in water ≥37 m. However, the percentage of rSI gray whales (30%) in shallow (<37 m) water in the northeastern Chukchi Sea was

significantly greater (χ^2= 47.5, p <0.001) than that expected based on the percentage of available shallow water habitat (11 %), indicating a preference for shallow (shoal) areas. Gray whales were usually (93%) seen in open water (O-1 0% ice cover).

15. Belukhas migrate through the study area from at least mid-September through October, and probably into November. Belukha distribution was dispersed in the Chukchi Sea, similar to bowhead whale distribution, but with proportionately more belukhas in waters north of720 N latitude.

16. The average depth at belukha sightings in the Beaufort Sea was significantly deeper than that in the Chukchi Sea (t= 7.26, p< 0.001), probably due to the differences in depths in the **two regions. A significantly greater percentage (97%) of rSI** belukhas **than expected** in the northeastern Chukchi Sea were seen **in water ≥37 m** deep ($\%^2$=10^5.7, p< O.001), indicating preference for deeper water. Most belukhas were seen in heavy (71-99% ice cover) ice conditions, although there was no correlation between ice condition and rSI sighting rates.

Recommendations

1. Because the onset of the bowhead whale fall migration into the Chukchi Sea cannot be determined by surveys that begin in late September, some aerial survey effort should be conducted in summer. Although the fall survey season likely covered most of the migration period, recent sightings of bowhead whales near Point Barrow in late summer suggest (Moore 1992) that whales sometimes occur in the study area four to five weeks before the onset of the surveys described here.

2. Passive acoustic monitoring conducted during the survey season from a field station in Barrow, as in 1987, would augment sighting data and increase the likelihood of detecting bowhead whales entering the Chukchi Sea. In 1987, bowhead calls were recorded three days before the first bowhead sighting of the

season, and 75% of all calls were recorded between 1900 and 2200 hours when surveys could not be conducted due to darkness (Moore et al. 1989a). Further, the potential availability of U.S. Navy/NOAA towed-array survey vessels could provide call localization capability on a mobile platform which, if applied to the Chukchi Sea study area, could delineate bowhead migration pathways better than visual sightings are ever likely to. Acoustic monitoring, unlike aerial surveys, can be fully operational during darkness and bad weather and provides robust data to support visual sightings (Thomas et al. 1986).

3. Predicting the occurrence of bowhead feeding aggregations east of Point Barrow would benefit future planning for OCS lease sites in the area. Some oceanographic features coincident with years that bowheads were seen feeding near Barrow may be definable via archived satellite data, depending on the images available for any given year (eg. Borstad 1987). In addition, efforts to sample waters near feeding whales would clarify the type of prey available to whales in that area. Both avenues of research require focused effort and funding if bowhead fall feeding patterns in the study area are to be better described.

4. Correlation of the bowhead migration corridor with oceanographic features in the Chukchi Sea could benefit from exploratory statistical analyses including multiple response permutation procedures (Mielke 1991). Because belukha distribution appears similar to that of bowheads, and the belukha data set is larger, analyses could be initially carried out on the belukha distribution data.

5. Bowhead whales have not been seen in the Hope Basin OCS Planning Area during fall aerial surveys, due either to the timing and extent of survey effort there or to bowhead migration corridors. Surveys directed towards survey blocks 22-25 in September and early October might better elucidate bowhead occurrence there. Further, such surveys could allow an assessment of the relative importance of Hope Basin as a feeding area for gray whales. Acoustic monitoring and call localization from a mobile platform, as suggested in Recommendation 2, could

greatly enhance understanding of both bowhead and gray whale migration timing and corridors in the Hope Basin.

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APPENDIX A

AERIAL SURVEY FLIGHT CAPTIONS, SURVEY TRACKS, AND SIGHTING SUMMARIES, 1991

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INTRODUCTION

This appendix consists of flight tracks 1 through 33, depicting aerial surveys flown over the Chukchi Sea study area from 20 September through 7 November 1991. Maps were generated by AutoCAD using a map digitized by the United States Geological Survey (Bauer 1989). Each map shows the flight track as a line drawn through position updates and/or sighting locations, as recorded on the aircraft computer system. Each symbol on the flight track/sighting charts represents one sighting of one or more animals. A caption describing the flight's objectives, survey conditions and sightings accompanies each map. Additionally, summary information on bowhead and gray whale sightings is presented beneath the flight caption in the tabularized format:

T#/C#	Total number of whales/total number of calves seen
LAT/LONG	Location (Latitude °N/longitude* W) in degrees, minutes, tenths
DIS	Perpendicular distance from the aircraft in meters
CUE	Sighting cue: BO = Body BW = Blow SP = Splash MP = Mud Plumes DY = Display IT = Ice Tracks
E3EH	Behavior SW = Swim DI = Dive RE = Rest MI = Mill DY = Display MT = Mate FE = Feed RL = Roll BR = Breach TS = Tail Slap cc = Cow-Calf DE = Dead St-i = Spy Hop NA = None
HDG	Heading (degrees magnetic)
ICE	Ice Cover (percent)
Ss	Sea State (Beaufort scale)
DEPTH	Depth (meters)

Dashes (-) indicate data were not recorded.

Summaries of daily flight effort (Table A-1) and marine mammal sightings (Table A-2) precede the flight tracks and provide an overview of survey effort and sighting data for the 1991 field season. Species abbreviations and symbols used in Table A-2 and on the flight tracks are as follows:

BH = Bowhead Whale (cl)

GW = Gray Whale (o)

BE = Belukha (A)

CT = Unidentified Cetacean (v)

PN = Unidentified Pinniped (∗)

WS = Walrus (◇)

BS = Bearded Seal (*)

RS = Ringed Seal (⌘)

PR = Polar Bear (X)

Table A-1, Summary of daily flight effort in the Chukchi Sea, 1991.

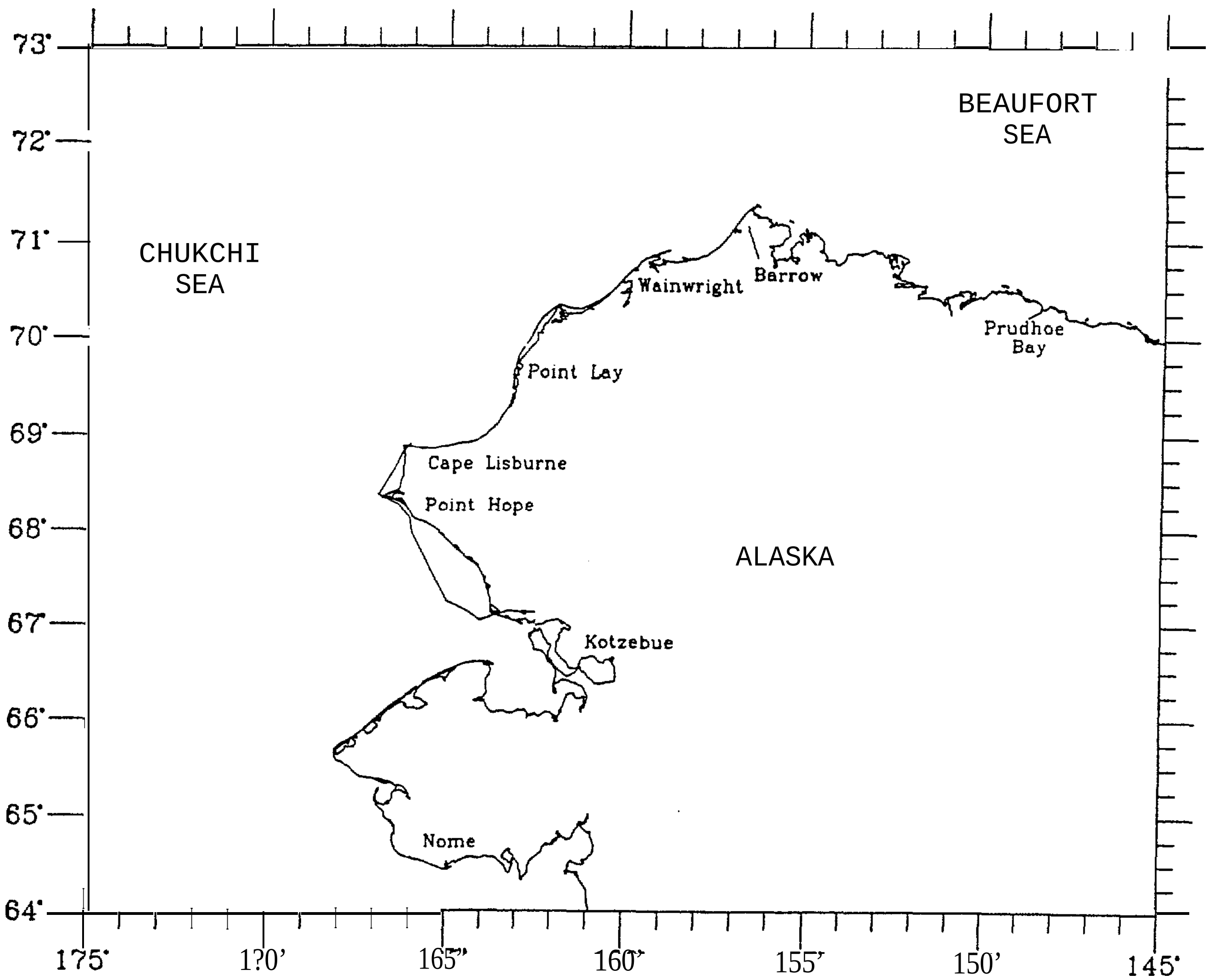
Date	Flt No.	Transect (km)	Connect (km)	Search (km)	Total (km)	Transect Time (h)	Total Time (h)
20 Sep	1	0	0	342	342	0	1.43
21 Sep	2	618	63	132	813	2.55	3.30
22 Sep	3	1118	70	133	1321	4.43	5.27
24 Sep	4	746	48	312	1106	3.05	4.63
27 Sep	5	0	0	233	233	0	1.22
28 Sep	6	0	0	209	209	0	0.85
29 Sep	7	1060	168	216	1444	4.58	6.36
1 Ott	8	527	“136	337	1000	2.32.	4.30
2 Ott	9	692	107	565	1364	2.75	5.47
3 Ott	10	1161	102	129	1392	4,93	5.92
4 Ott	11	142	12	193	347	0.55	1.35
5 Ott	12	1098	150	282	1530	4.60	6.32
6 Ott	13	421	84	157	662	1.76	3.03
7 Ott	14	443	25	443	911	1.85	4.19
8 Ott	15	210	32	59	301	0.90	1.32
9 Ott	16	554	169	136	859	2.30	3.57
12 Ott	17	659	105	567	1331	2.75	5.57
13 Ott	18	658	93	686	1439	2.72	5.93
14 Ott	19	656	79	268	1003	2.73	4.08
15 Ott	20	1068	111	268	1447	4.27	5.83
16 Oct	21	373	69	461	903	1.62	3.77
17 Ott	22	308	78	335	721	1.22	2.93
20 Ott	23	1134	98	104	1336	4.62	5.50
22 Ott	24	655	170	422	1247	2.55	4.85
23 Ott	25	774	127	606	1507	3.10	6.65
24 Ott	26	996	78	507	1581	3.95	6.18
25 Oct	27	266	101	288	655	1.12	2.70
28 Ott	28	403	70	355	828	1.63	3.48
31 Ott	29	715	97	413	1225	2.78	5.28
1 Nov	30	499	38	603	1140	1.95	4.44
2 Nov	31	108	0	490	598	0.37	2.20
5 Nov	32	708	123	212	1043	2.80	4.13
7 Nov	33	0	0	458	458	0	1.83
TOTAL	33	18770	2603	10921	32294	76.75	133.78

Table A-2. Summary of daily marine mammal sightings by species, 1991. Number of sightings/number of animals. [* = 1 ribbon seal]

Date	Flt No.	BH	GW	BE	WS	BS	RS	PN	PB
20 Sep	1	0	o	0	0	0	o	1/1	0
21 Sep	2	0	0	10/19	0	0	0	1/1	1/1
22 Sep	3	0	1/1	9/77	26/21 75	2/6	1/3	7/1 o	1/1
24 Sep	4	0	3/3	6/12	27/1925	o	o	3/3’	o
27 Sep	5	0	1/1	1/1	o	1/1	2/3	8/10	0
28 Sep	6	0	o	3/31	0	o	o	o	0
29 Sep	7	3/3	3/3	4/6	1 0/75	0	0	4/4	2/2
1 Ott	8	o	9/14	3/3	4/12	0	0	52/102	0
2 Ott	9	0	1/1	3/3	35/477	0	0	6/6	1/1
3 Ott	10	3/5	o	14/16	o	0	0	5/20	1/1
4 Ott	11	o	0	1/1	0	0	0	2/2	0
5 Ott	12	0	0	8/50	28/594	0	0	1/1	0
6 Ott	13	8/1 1	1/1	9/22	o	0	0	7/7	2/2
7 Ott	14	1/1	1/2	1/4	28/68	3/3	0	13/20	1/1
8 Ott	15	1/1	o	o	o	1/1	0	9/20	0
9 Ott	16	o	0	2/3	2/250	2/2	0	27/30	2/2
12 Ott	17	0	0	o	11/63	o	0	5/6	0
13 Ott	18	1/1	0	12/22	36/763	0	0	8/1 1	0
14 Ott	19	o	0	23/182	3/4	0	0	8/9	1/1
15 Ott	20	0	0	1/7	4/4	5/5	0	12/13	0
16 Oct	21	1/1	0	o	o	1/1	0	14/23	0
17 Ott	22	o	0	1/2	16/1077	3/3	0	9/9	0
20 Ott	23	0	0	o	o	2/2	0	4/4	1/1
22 Ott	24	0	0	0	0	o	0	7/7	0
23 Ott	25	5/5	0	3/5	4/30	0	0	12/14	0
24 Ott	26	o	0	6/9	9/54	1/1	0	26/28	2/4
25 Ott	27	0	0	o	2/2	o	0	9/9	0
28 Ott	28	0	0	0	o	0	0	4/4	2/2
31 Ott	29	4/4	0	0	0	0	0	13/14	1/9
1 Nov	30	o	0	0	0	0	0	4/6	0
2 Nov	31	0	0	0	0	0	0	5/5	0
5 Nov	32	0	0	0	0	0	0	17/912	0
7 Nov	33	0	0	0	0	0	0	o	0
Total	33	27/32	20/26	120/475	245/7573	21/25	3/6	303/131 1	1 8/28

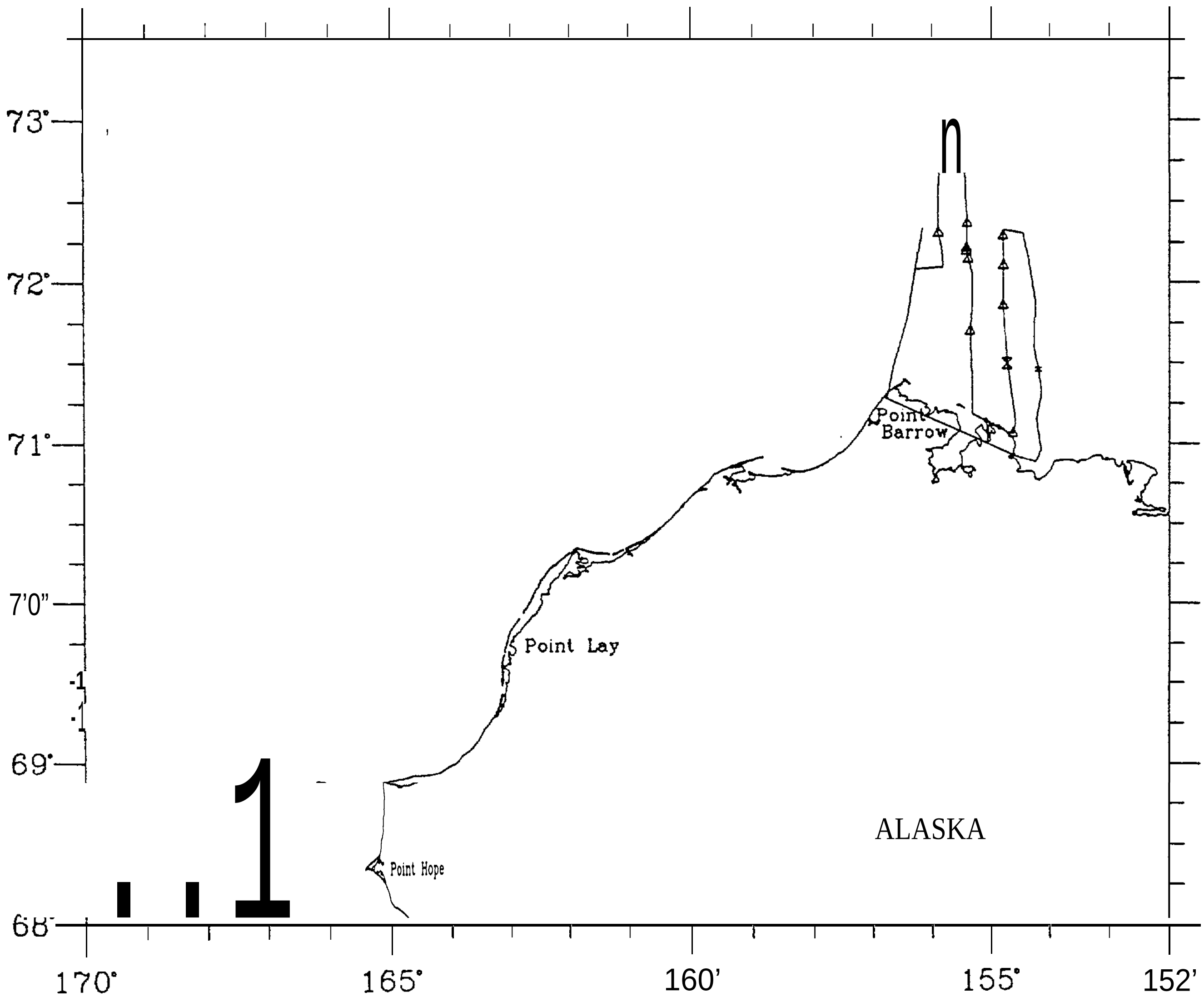
Flight 1:20 September 1991

Flight was a search survey in blocks 22 and 30 enroute to Barrow; the onset of darkness precluded surveying blocks north of Cape Lisburne. Weather was overcast, with some precipitation. Visibility ranged from < 1 to unlimited and sea state was Beaufort 2-3. One unidentified pinniped was seen.



Flight 2: 21 September 1991

Flight was a transect survey of portions of blocks 12 and 12N. There was 80-99% ice cover in block 12N, while block 12 had 15-40% ice cover. Weather was fog and overcast. Visibility was generally <1 km over open water areas, and up to 5-10 km over ice covered areas. Sea state ranged from Beaufort O-3. Belukhas, an unidentified pinniped and a polar bear were seen.

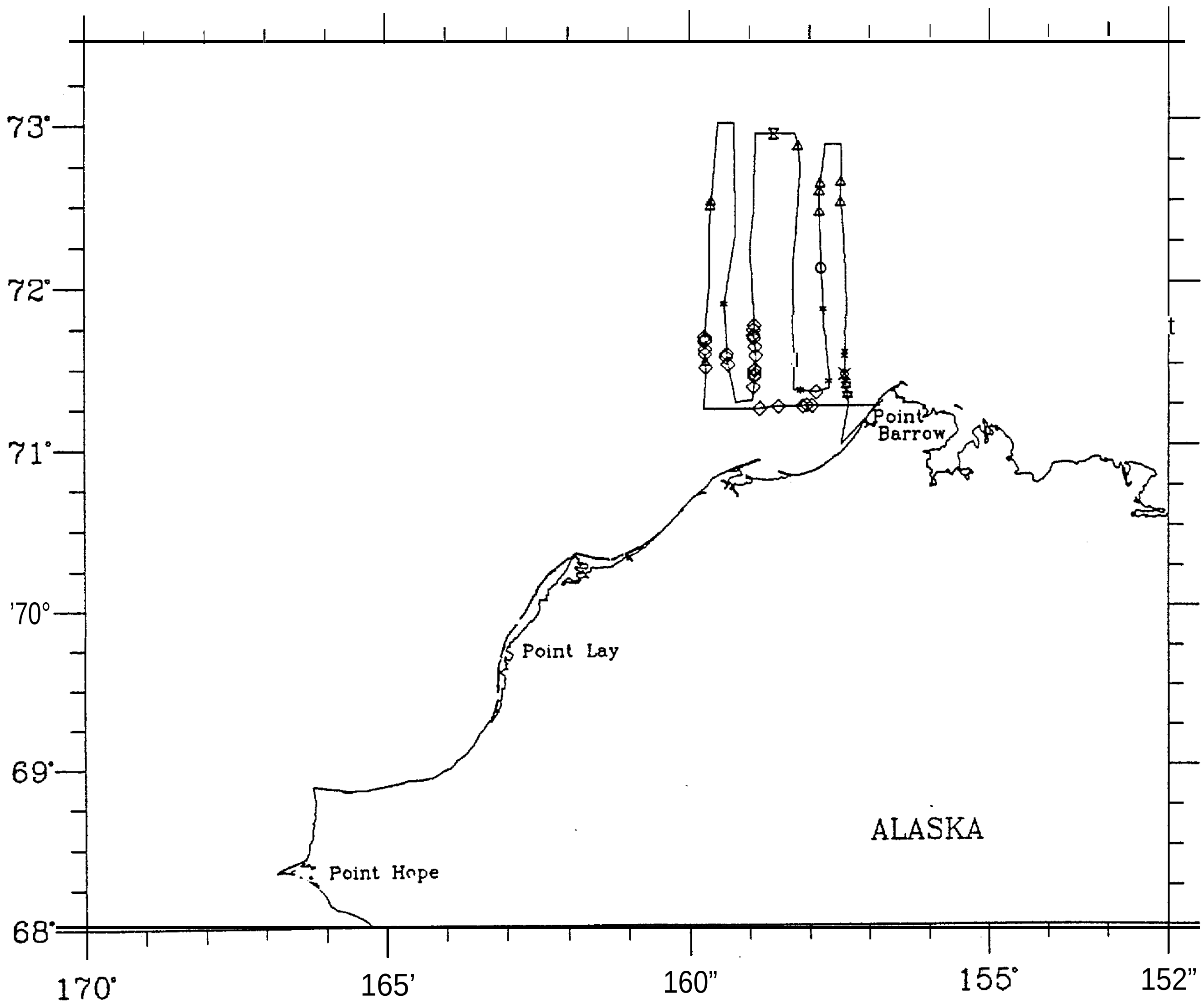


Flight 3: 22 September 1991

Flight was a transect survey in blocks 13 and 13N. Ice cover in block 13N was 60-99%, with 10-20% ice cover north of 71020" N in block 13, and open water south of there. Weather was overcast with some areas of fog. Visibility was often unlimited, although occasionally reduced to <1 km. Sea state was Beaufort O-2. **One juvenile gray whale was seen, as well as belukhas, walruses, pinnipeds and a polar bear.**

Gray Whale

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	72"05.9	157048.7	415	60	SW	240	80	B0	68

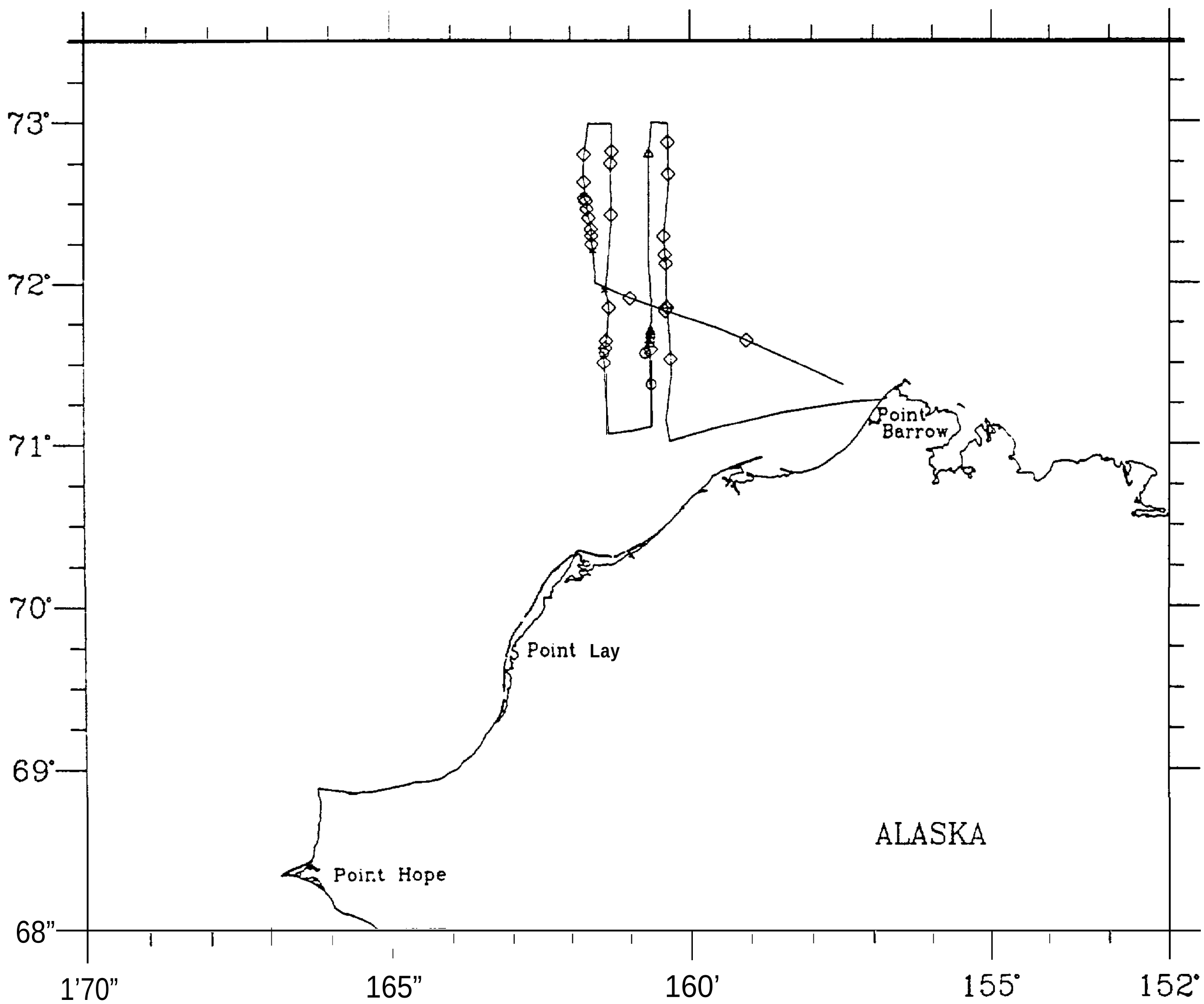


Flight 4: 24 September 1991

Flight was a transect survey in portions of blocks 14 and 14N. **Ice** cover was **99%** in block 14N, and ranged from 0-40% in block 14. Weather was mostly clear with some fog and low ceilings. Visibility ranged from O km to unlimited. Sea state was Beaufort O-2. One adult and two immature gray whales were seen feeding. Belukhas, walruses, unidentified pinnipeds and one ribbon seal were also seen.

Gray Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71 ‘33.8	160045.0	-	MP	FE	360	5	1	49
1/0	71022.1	160038.6	-	MP	FE	360	5	1	38
1/0	71034.0	161026.0	544	MP	FE	230	10	2	42

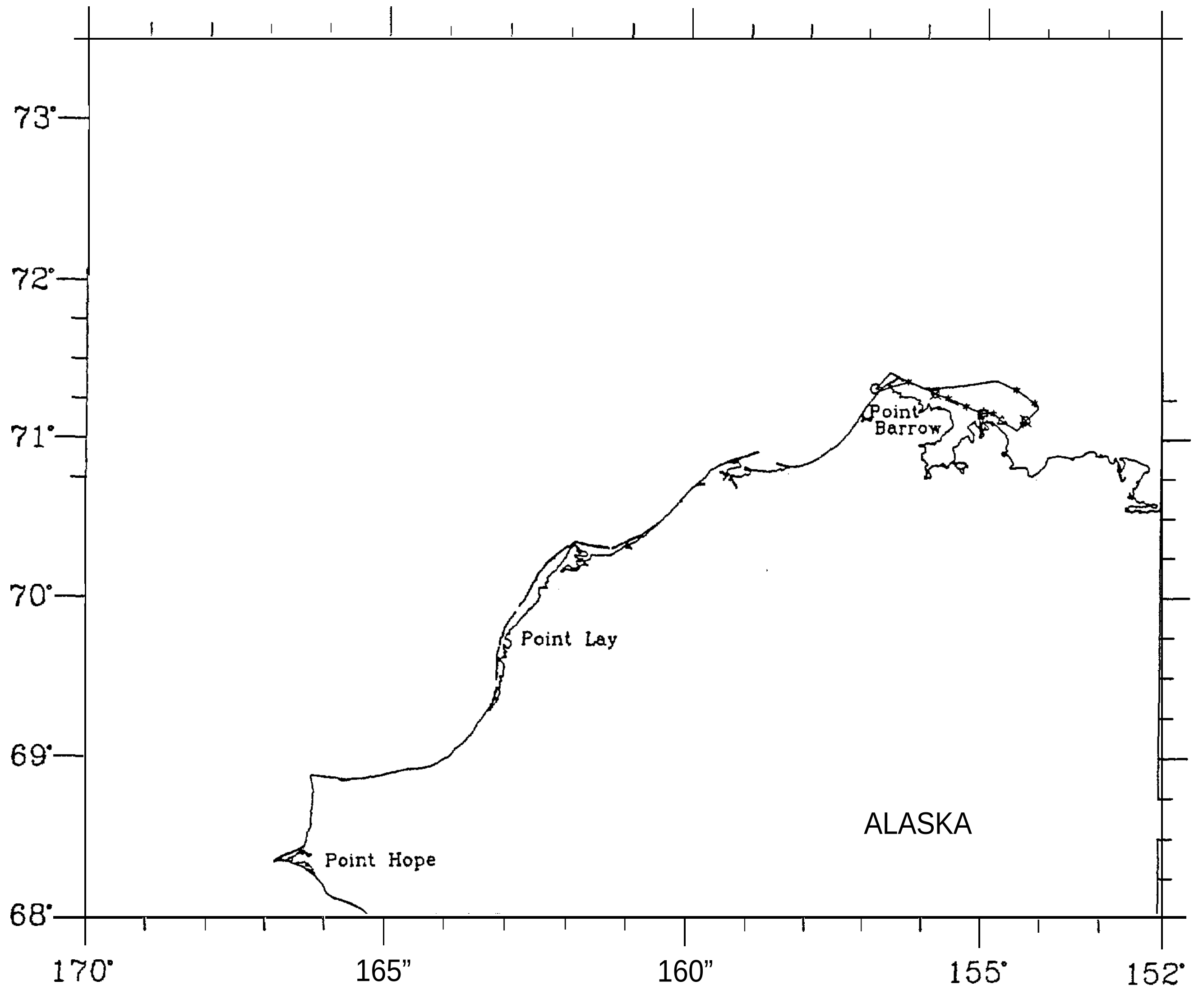


Flight 5: 27 September 1991

Flight was a search survey in block 12, which was aborted due to fog, low ceilings and visibility < 1 km. Ice cover was 5-15%, and sea state was Beaufort 1-2. One adult gray whale was seen feeding just west of Barrow. A belukha, a bearded seal, ringed seals and unidentified pinnipeds were also seen.

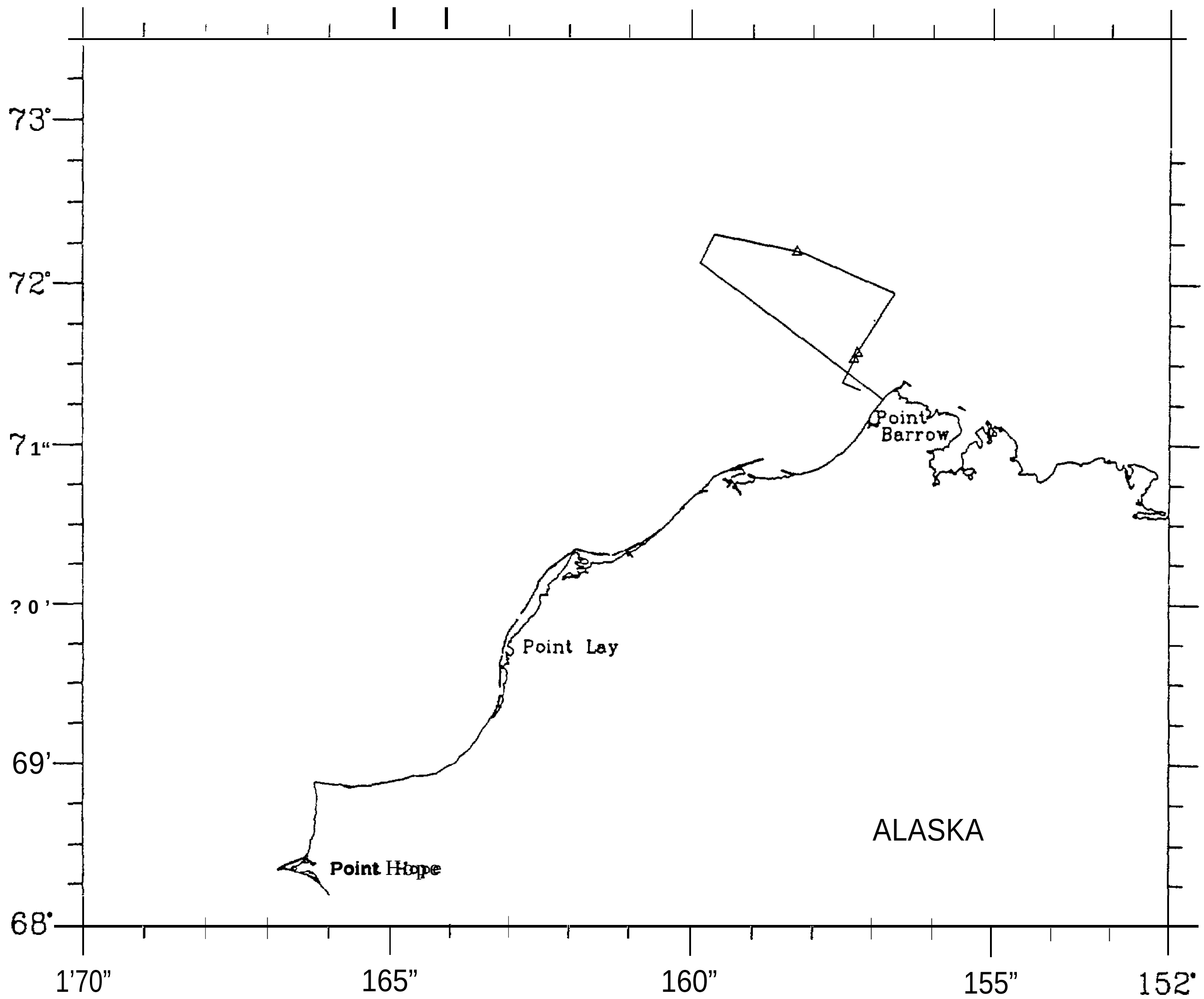
Gray Whale

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	m
1/0	71019.0	156050.0	-	BO	FE	330	15	1	33



Flight 6: 28 September 1991

Flight was a search survey through portions of blocks 13 and 14. Weather was fog and visibility was generally c 1 km. Ice cover was approximately 50%, and sea state was Beaufort O. Belukhas were seen.



Flight 7: 29 September 1991

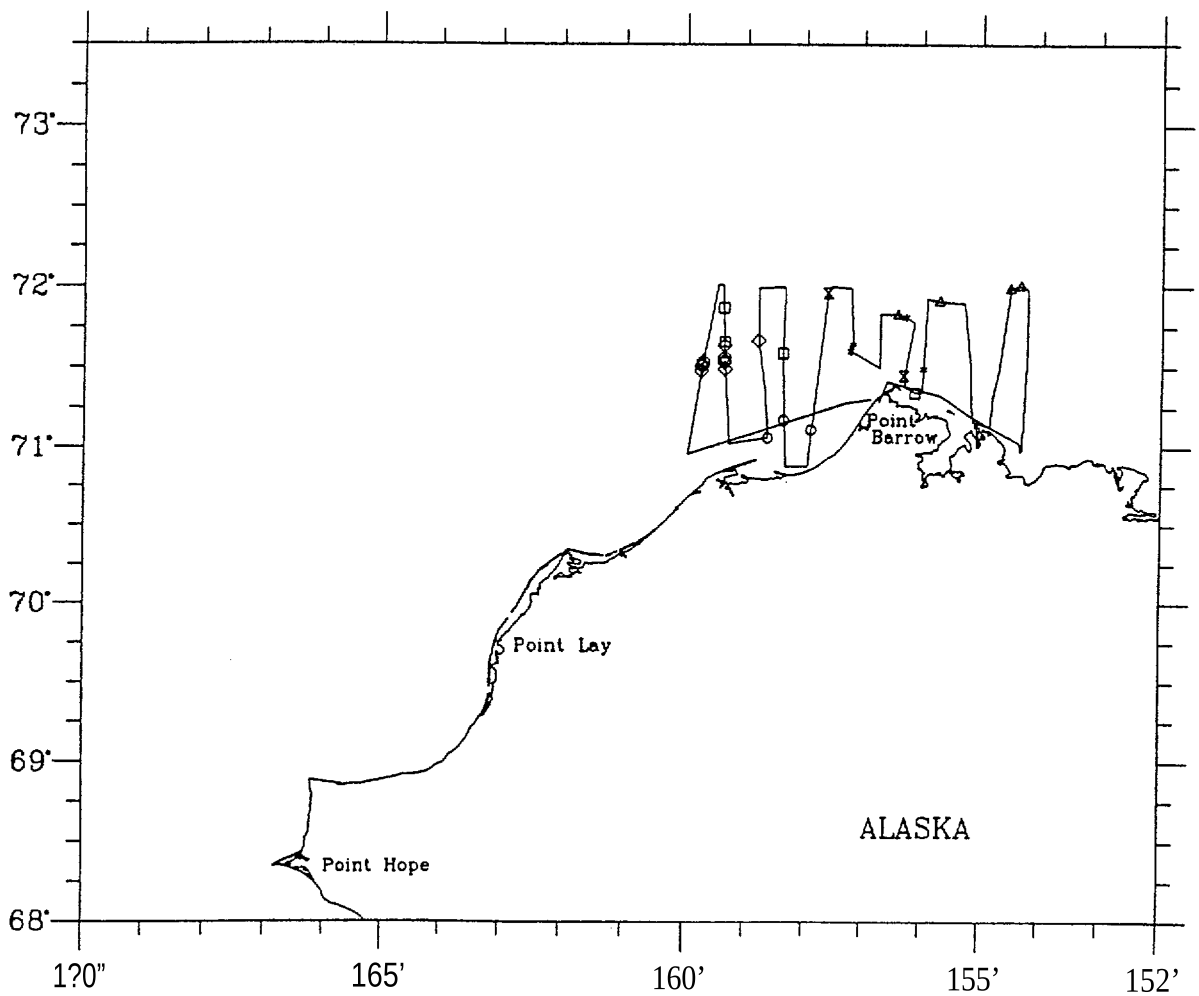
Flight was a transect survey in blocks 12 and 13. Ice cover was 60-99% in the northern third of the survey area, 10-50% north of 710 15'N, with open water 'south of there. Weather was overcast with areas of low ceilings. Visibility was generally 5-10 km, and sea state was Beaufort O-2. Three bowhead whales, including a large adult with an all white tail, and three gray whales were seen. Belukhas, walruses, unidentified pinnipeds, polar bears and one small bowhead carcass were also seen.

Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	S s	DEPTH
1/0	71035.2	158023.2	185	BO	SW	240	30	2	48
1/0	71039.6	159021.3	272	60	SW	240	30	1	35
1/0	71 '52.3	159022.5	244	BO	SW	240	90	1	40

Gray Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	S s	DEPTH
1/0	71006.6	157"53.7	644	BO	FE	---	1	3	38
1/0	71010.3	158021.8	-	MP	FE	---	20	3	46
1/0	71003.6	158038.1	-	MP	FE	130	0	4	26

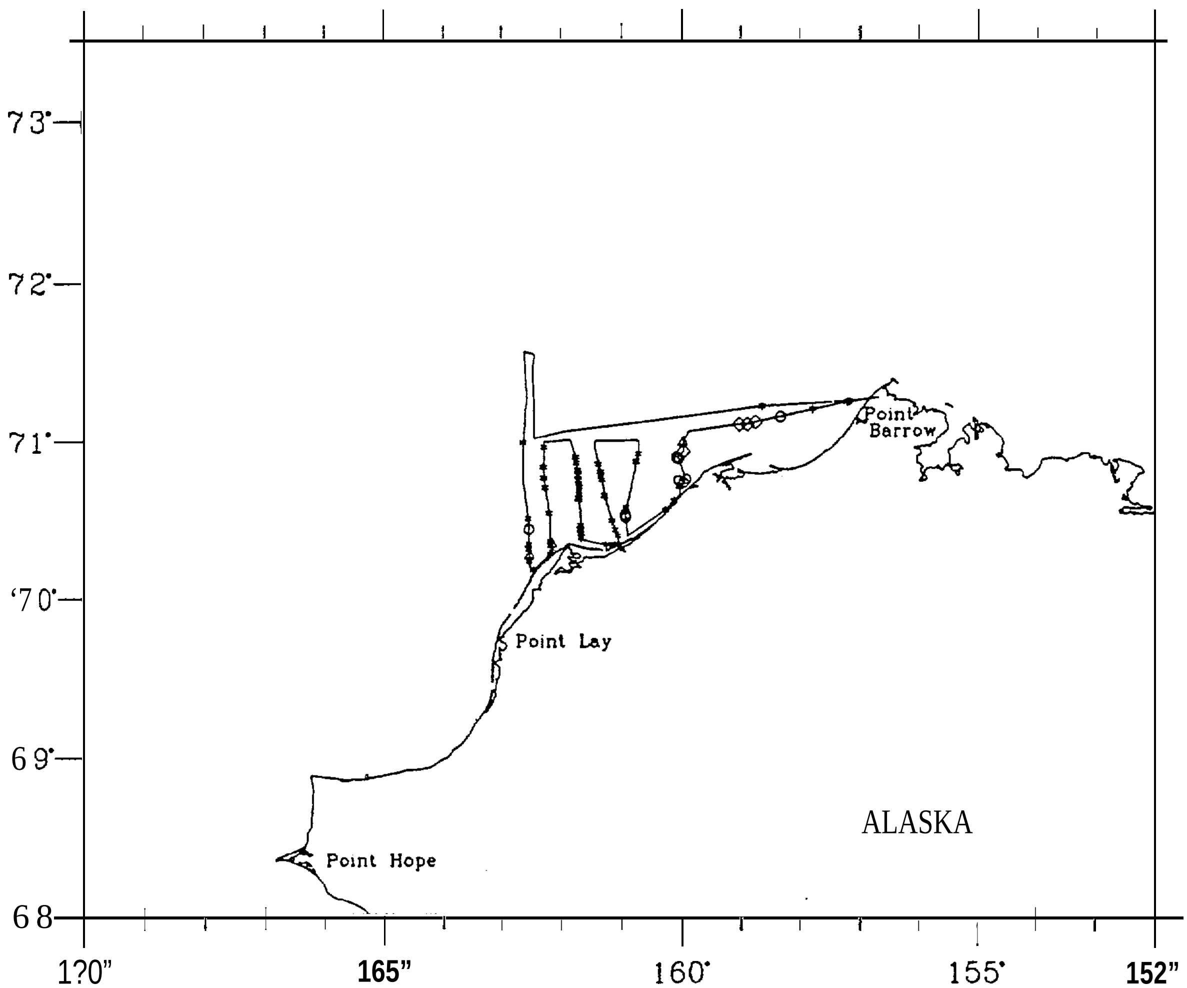


Flight 8: 1 October 1991

Flight was a transect survey in portions of blocks 14 and 17. Except for 20% ice cover in block 14, the **survey area was ice-free. Weather was clear and partly cloudy with unlimited visibility in** block 17, with low-lying fog in block 14. Sea state was Beaufort 1-2. Fourteen gray whales were seen in blocks 13 and 17. Belukhas, walruses, and unidentified pinnipeds were also seen.

Gray Whales

T#/C#	I-AT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70026,0	162032,4	163	SP	SW	220	0	2	22
1/0	70031.6	160056.8	383	60	FE	270	0	1	20
1/0	70030.8	160"56.1	408	MP	FE	270	0	1	20
2/0	70044.8	160003.0	2284	BL	SW	260	0	1	22
1/0	70044.2	159057.8	-	BL	SW	260	0	1	18
1/0	70045.4	159055.3	-	BL	SW	260	0	1	24
1/0	70"53.2	160003,0	1259	BL	SW	150	0	1	49
3/0	70"53.7	160005.2	-	BL	FE	---	0	1	-49
3/0	71 "09.4	158"20.0	2571	BO	FE	230	0	1	37

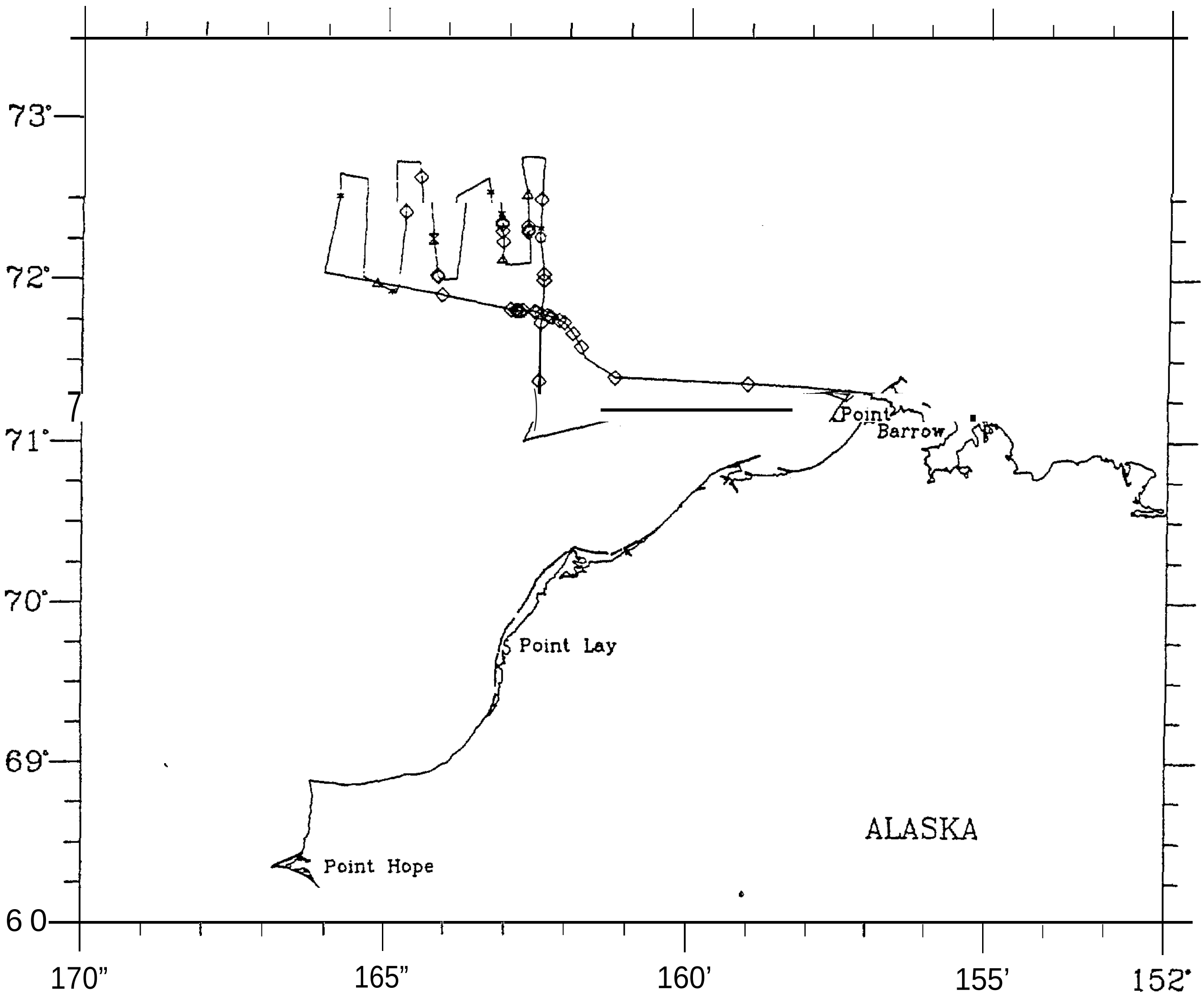


Flight 9: 2 October 1991

Flight was a transect survey in portions of blocks 14, 14N and 15N. Ice cover north of 71° N was 60-99%, with open water south of there. Weather was fog with limited areas of partly cloudy conditions. Visibility ranged from <1 km to unlimited. Sea state was Beaufort O-3. One gray whale was seen, as well as belukhas, walruses and unidentified pinnipeds.

Gray Whale

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	m
1/0	72 °15.5	162028.2	536	MP	FE	60	90	1	38

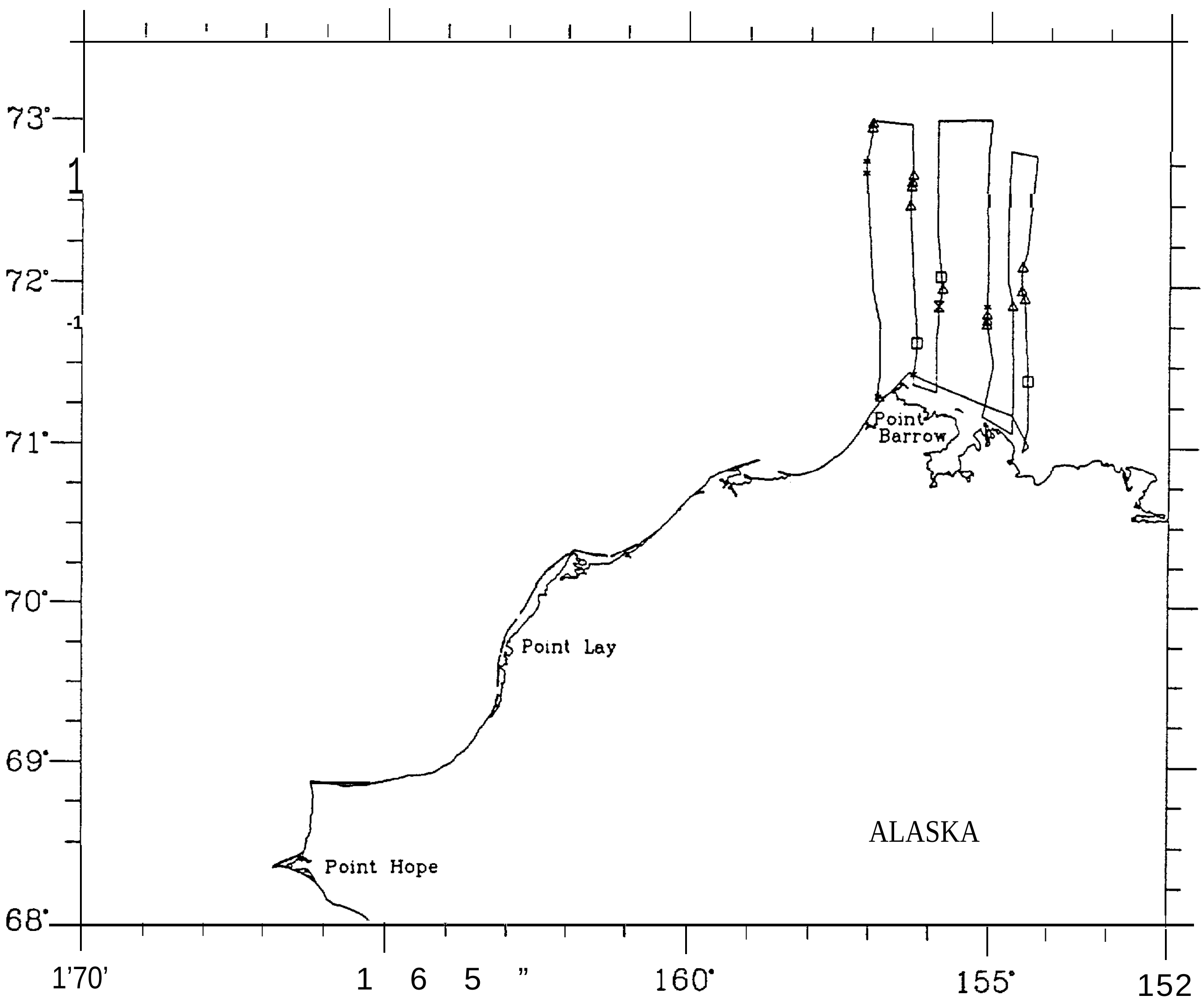


Flight 10: 3 October 1991

Flight was a transect survey in blocks 12 and 12N. Ice cover in block 12N was 60-99%, and 20-50% in block 12. Weather was overcast and partly cloudy, with unlimited visibility. Sea state was Beaufort O-2. Five bowhead whales were sighted, including two cow-calf pairs. Belukhas, a polar bear, and unidentified pinnipeds were seen.

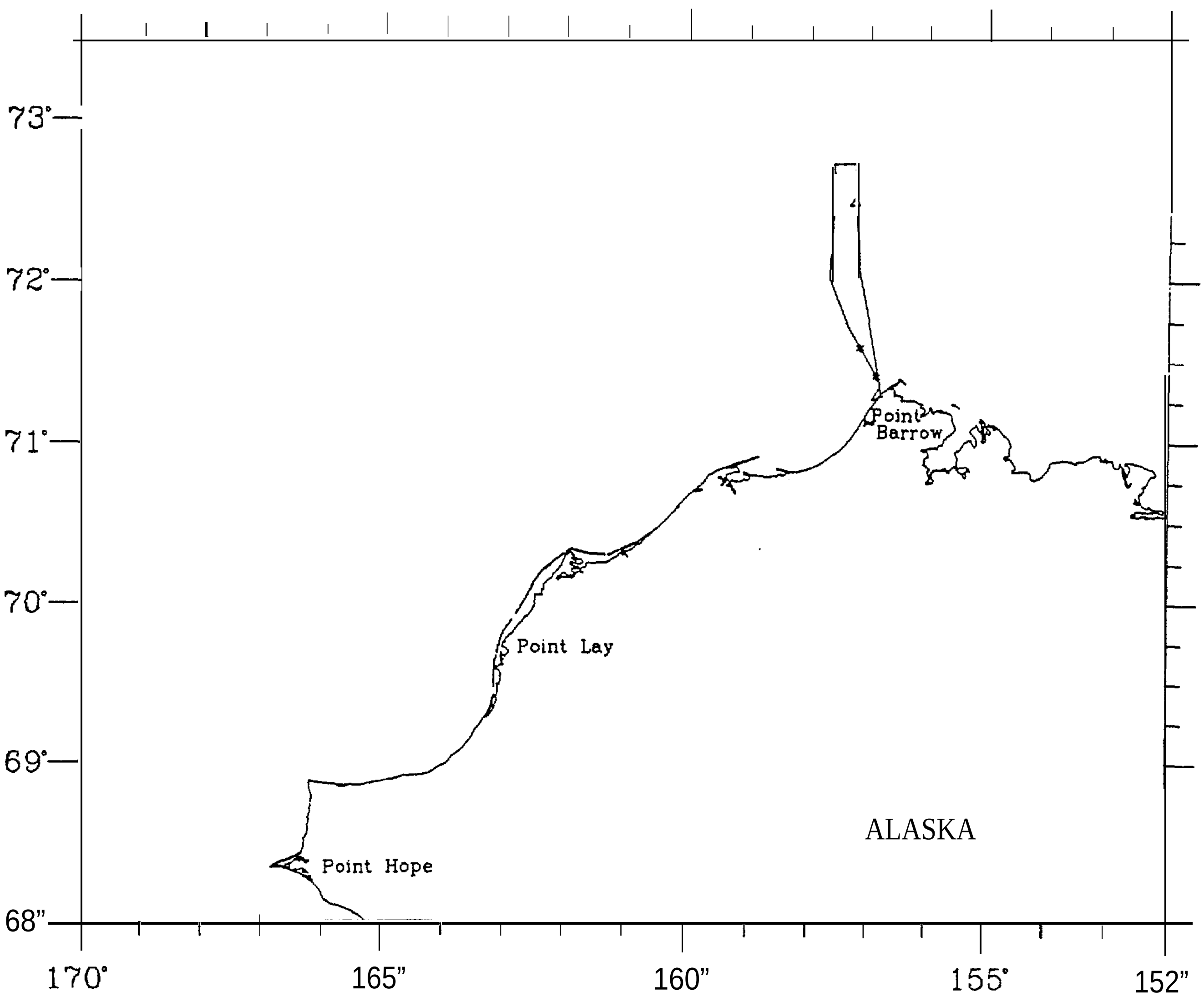
Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71024.6	154021.5	285	BO	SW	30	60	1	24
2/1	72"03.2	155049.2	214	BO	SW	60	90	1	247
2/1	71038.8	156 °12.9	1072	BO	RE	260	0	2	123



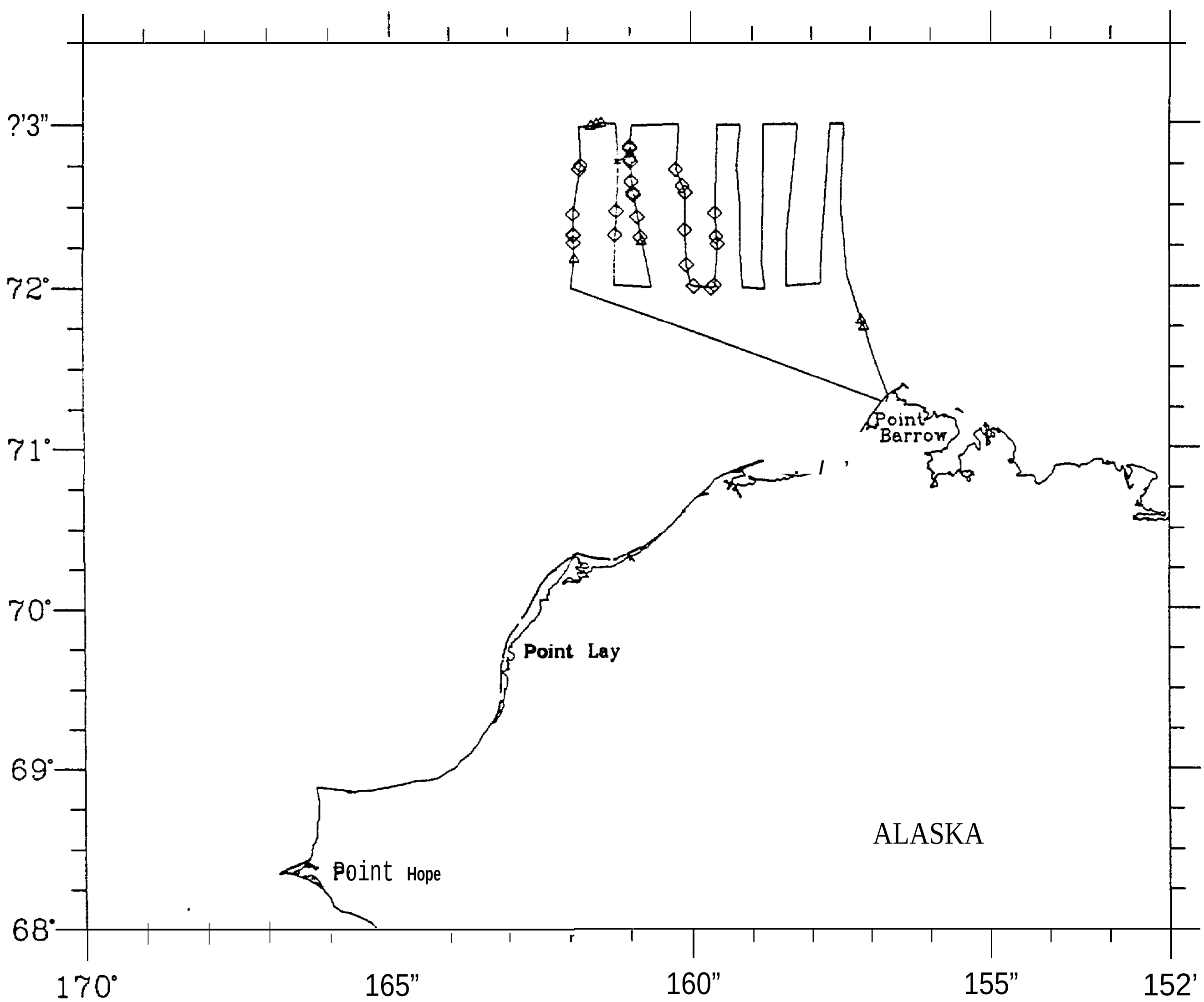
Flight 11: 4 **October 1991**

Flight was a transect survey of the eastern one-third of block 13N. Ice cover north of 71 °20'N was 95-99%, with open water south of there. Weather was fog and low ceilings, with visibility ranging from O-5 km. Sea state was Beaufort 0-1. One belukha and unidentified pinnipeds were seen.



Flight 12: 5 October 1991

Flight was a transect survey in blocks 13N and 14N. Ice cover in 13N and the eastern one-third of 14N was 95-99%, with 50% ice cover in block 14N west of 1610 15'W. Weather was partly cloudy with unlimited visibility, and sea states were Beaufort O-1. Belukhas, walruses and an unidentified pinniped were seen.



Flight 13: 6 October 1991

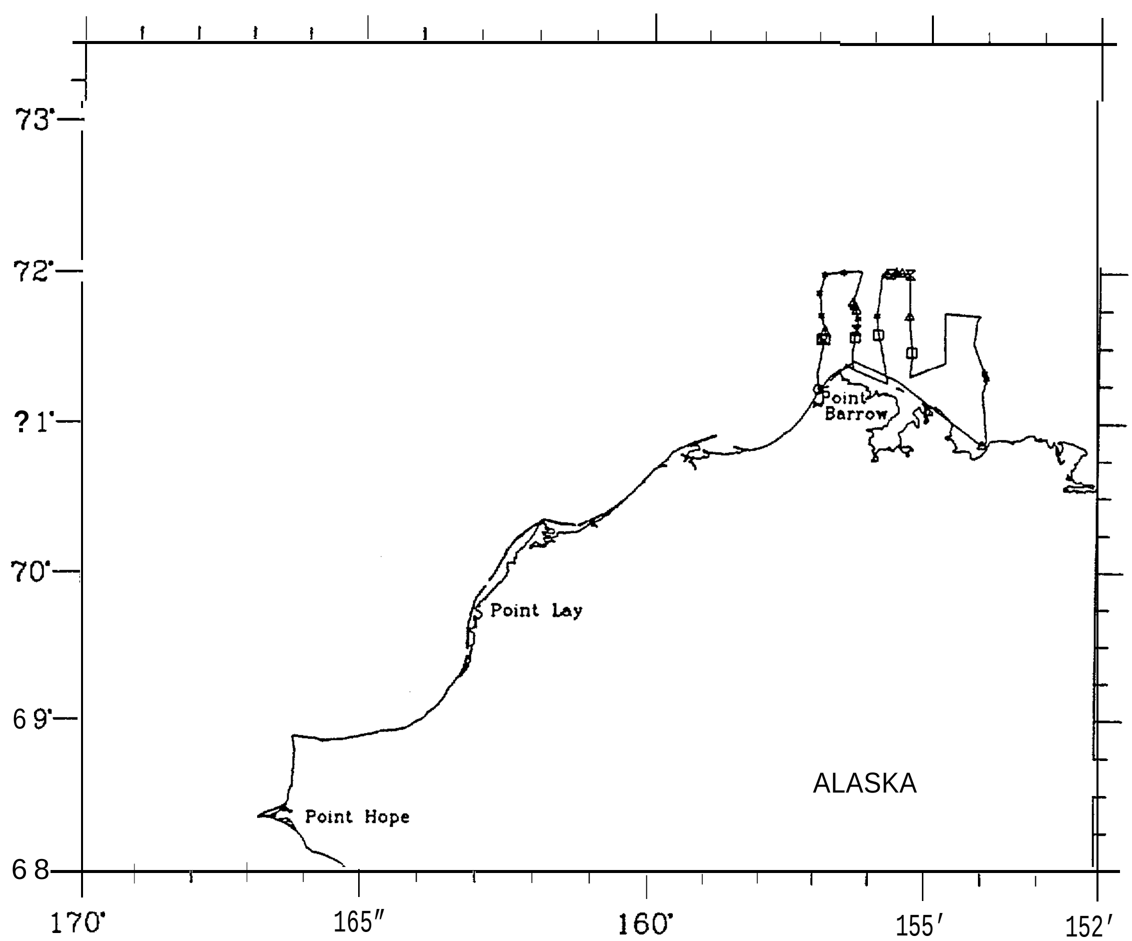
Flight was a transect survey in block 12. Ice cover north of 71” 35’N was 60-99%. Weather was overcast with patches of fog and precipitation. Visibility ranged from O to 5-10 km, and sea state was Beaufort 1-3. Eleven bowhead whales were seen, including one very large adult. One gray whale was seen feeding near Barrow approximately 37km (20 nmi) from the nearest bowhead sighting. Belukhas, polar bears, and unidentified pinnipeds were also seen.

Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71028,6	155 °18.2	301	SP	Sw	110	10	2	11
1/0	71 ‘59,8	155041.2	561	BO	SW	60	75	1	150
1/0	71 “35,8	155”54.0	286	BO	Sw	190	80	1	221
1/0	71 *34.7	156 °18.9	654	BO	Sw	220	80	1	161
2/0	71033.6	156050.6	823	BO	SW	180	95	1	102
2/0	71034.0	156054.8	-	00	SW	220	95	1	102
1/0	71033.7	156051.9	-	BO	SW	210	95	1	102
2/0	71033.6	156”55.2	-	80	Sw	180	95	1	102

Gray Whale

1/0	71013.7	156”58.4	-	MP	FE	---	0	4	18

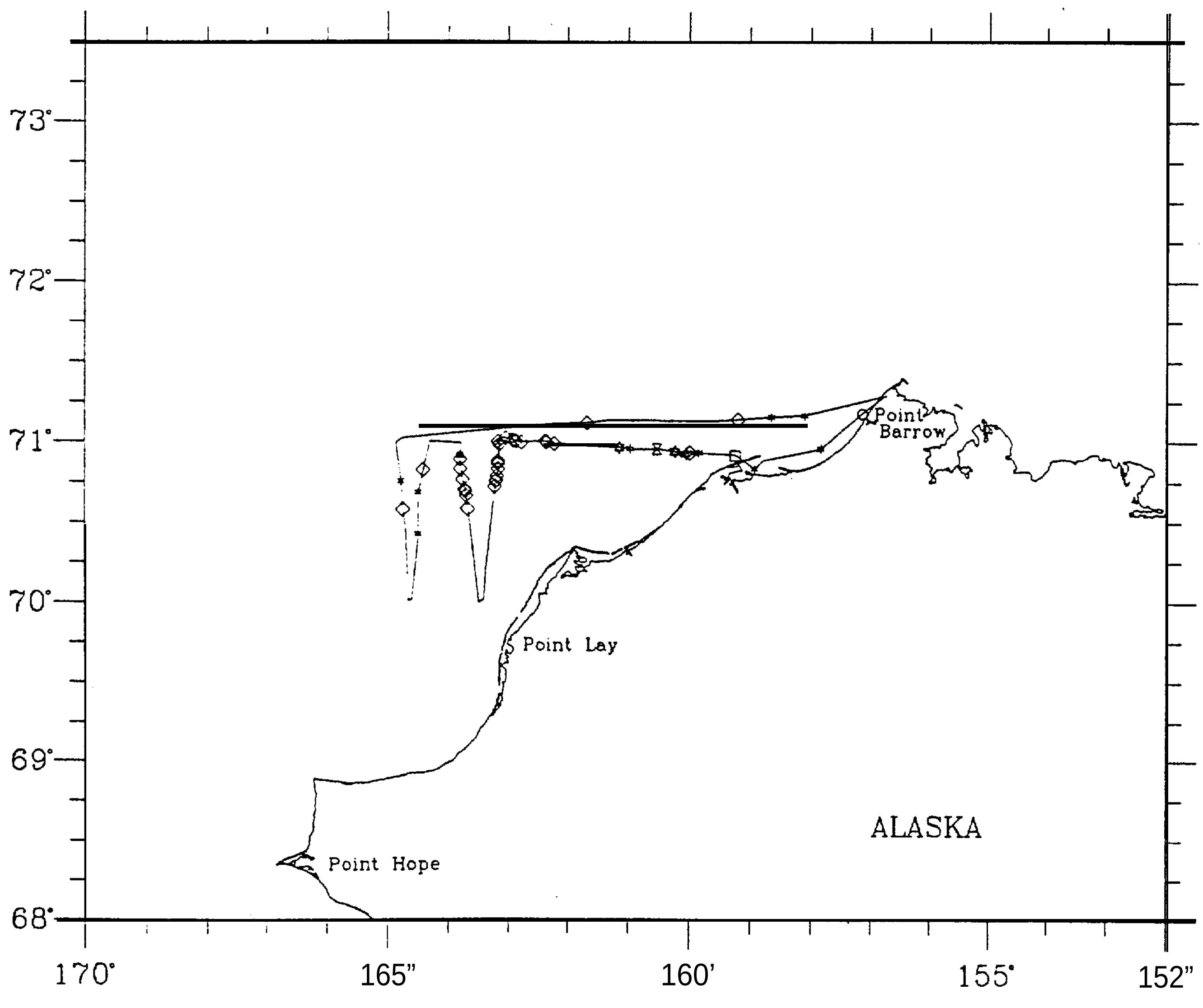


Flight 14: 7 October 1991

Flight was a transect survey in block 18, with a search survey through blocks 13, 14, 15 and 17. Ice cover in the northern half of block 18 was 95-99% new ice, with open water south of there. Weather was overcast with some areas of low ceilings. Visibility ranged from < 1 km to unlimited, and sea state was Beaufort 1-3. One bowhead and two feeding gray whales were seen. Belukhas, walruses, bearded seals, unidentified pinnipeds and a polar bear were also seen.

Bowhead Whale

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70"54.9	159"13.3	-	BO	SW	210	95	1	29
Gray Whales									
2/0	71010,6	157007.7	693	BL	FE	---	0	2	18

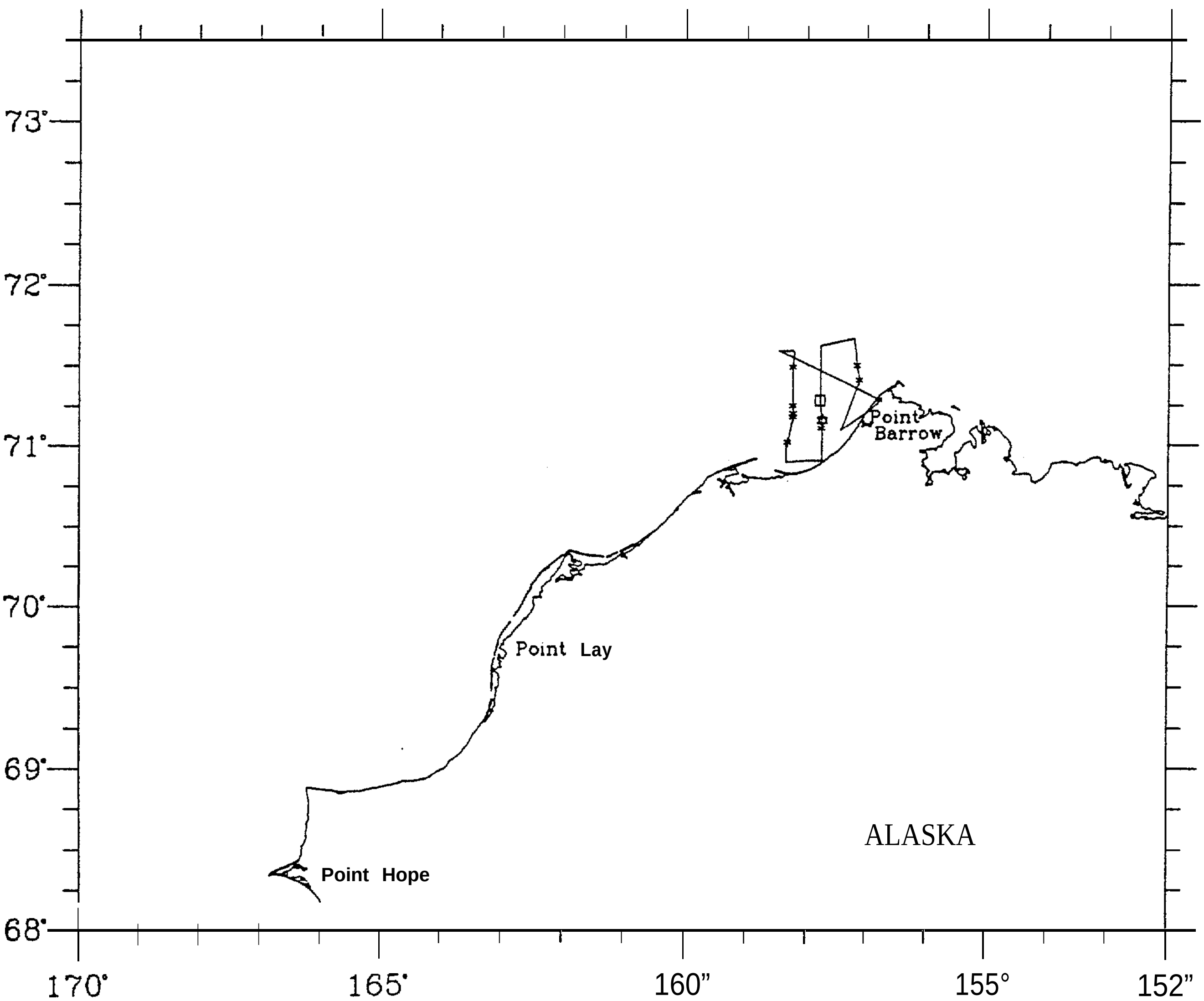


Flight 15: 8 October 1991

Flight was a transect survey in portions of block 13. Ice cover was 80-99% new ice. Weather was overcast with snow flurries and visibility ranged from 0-5 km. Sea state was Beaufort O-1. One bowhead whale was seen swimming slowly. A bearded seal and unidentified pinnipeds were also seen.

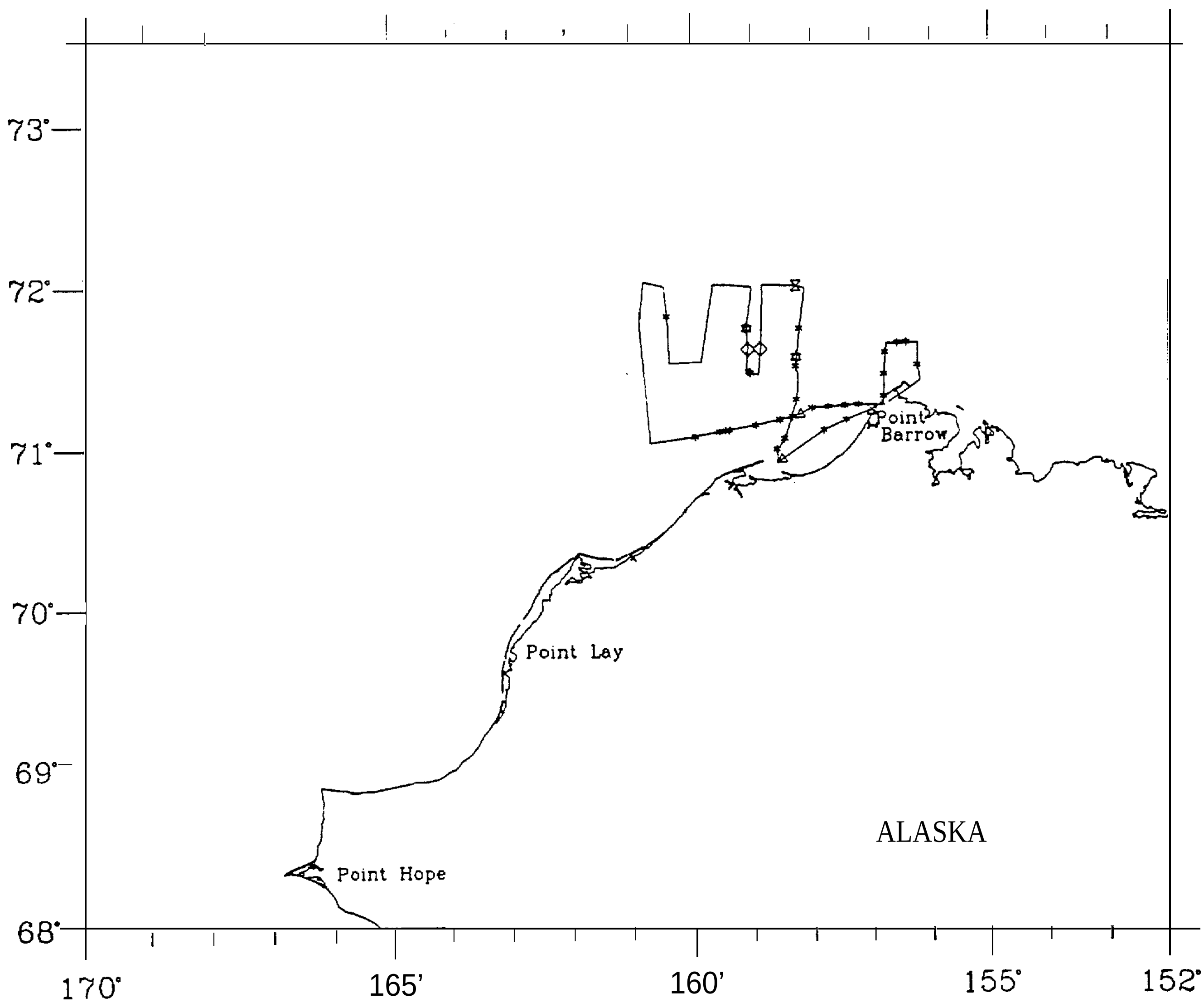
Bowhead Whale

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71016.8	157046.1	292	BO	SW	190	98	0	55



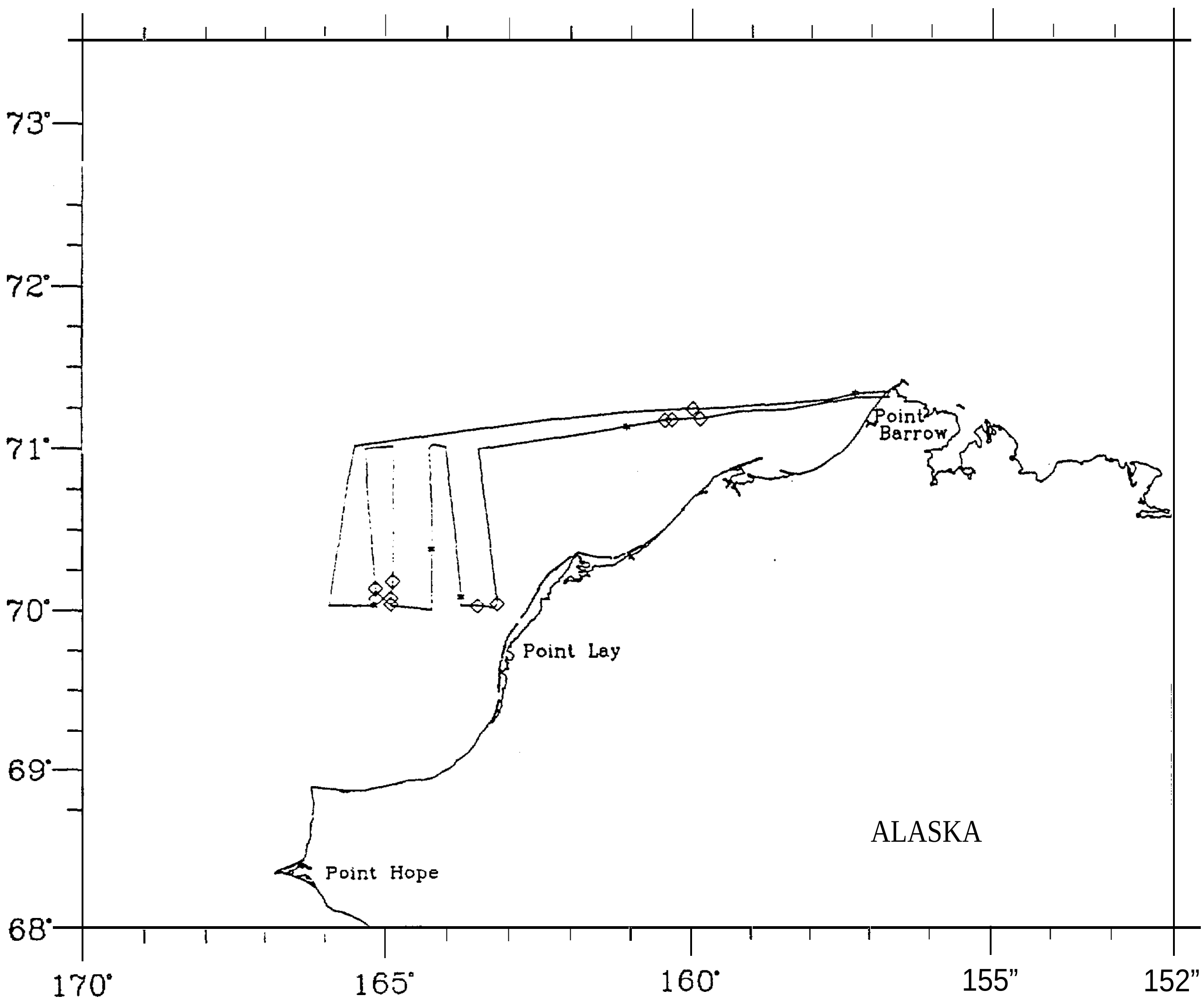
Flight 16: 9 October 1991

Flight was a transect survey in portions of blocks 12, 13 and 14. Ice cover was 90-99%. Weather was overcast with large areas of fog, and visibility ranged from <1 to 10 km. Sea state was Beaufort O. Belukhas, walruses, bearded seals, unidentified pinnipeds and polar bears were seen.



Flight 17: 12 October 1991

Flight was a transect survey in block 18. Ice cover was 50-90% new ice north of 710 N, with open water south of there. Weather was overcast with areas of fog and low ceilings, and visibility ranged from from <1 km to unlimited. Sea state was Beaufort 1-5. Walruses and unidentified pinnipeds were seen.

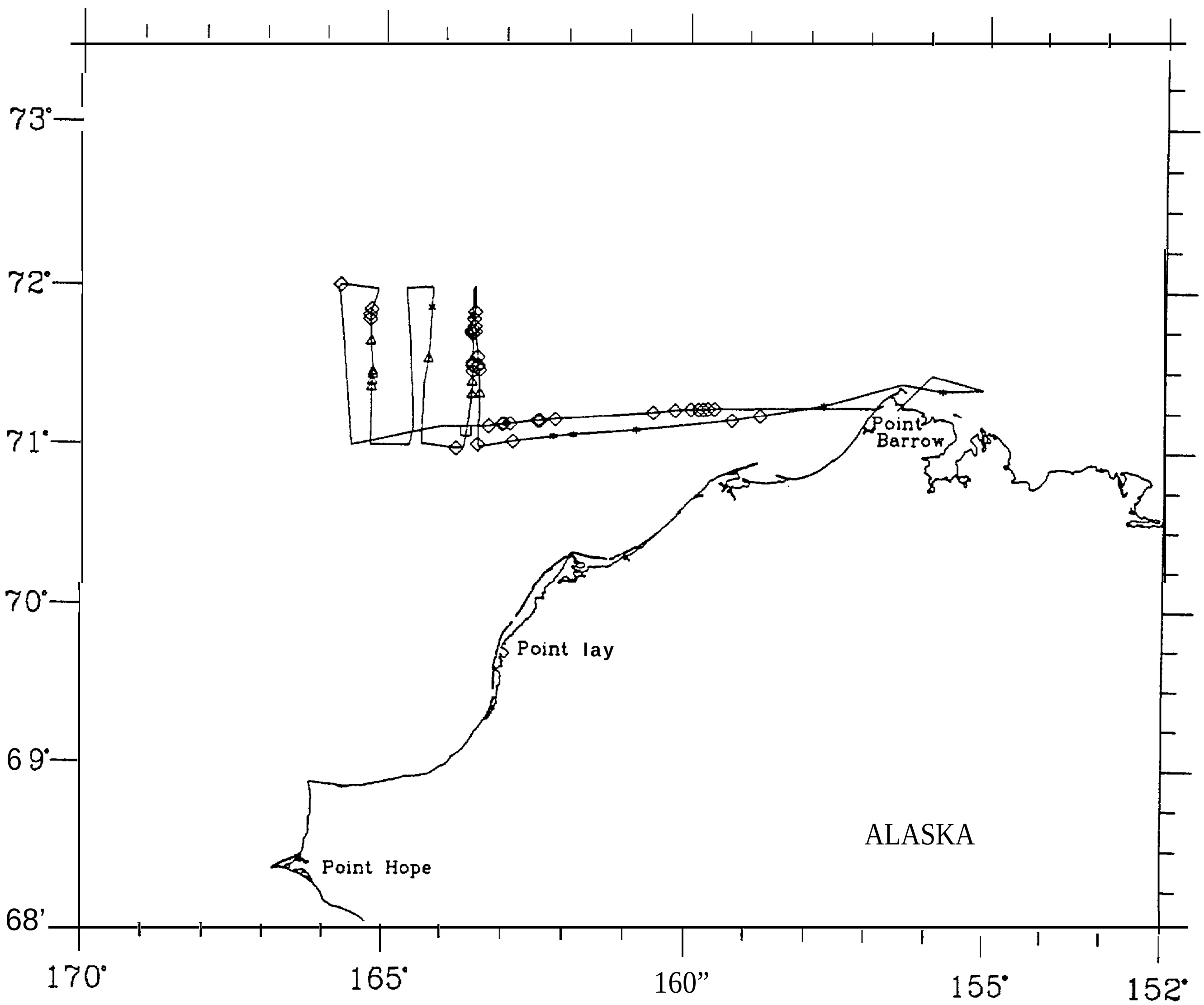


Flight 18: 13 October 1991

Flight was a transect survey in block 15. Ice cover was 60-80% north of 710 20'N, with 80% new ice in block 13. Weather was overcast and visibility ranged from 5-10 km. Sea state was Beaufort O-4. One bowhead whale calf was seen swimming fast. The calf was grey in color with a white chin patch and repeatedly lunged out of the water as it surfaced. No adult whale was seen during 10 minutes of circling. Belukhas, bearded seals and unidentified pinnipeds were also seen.

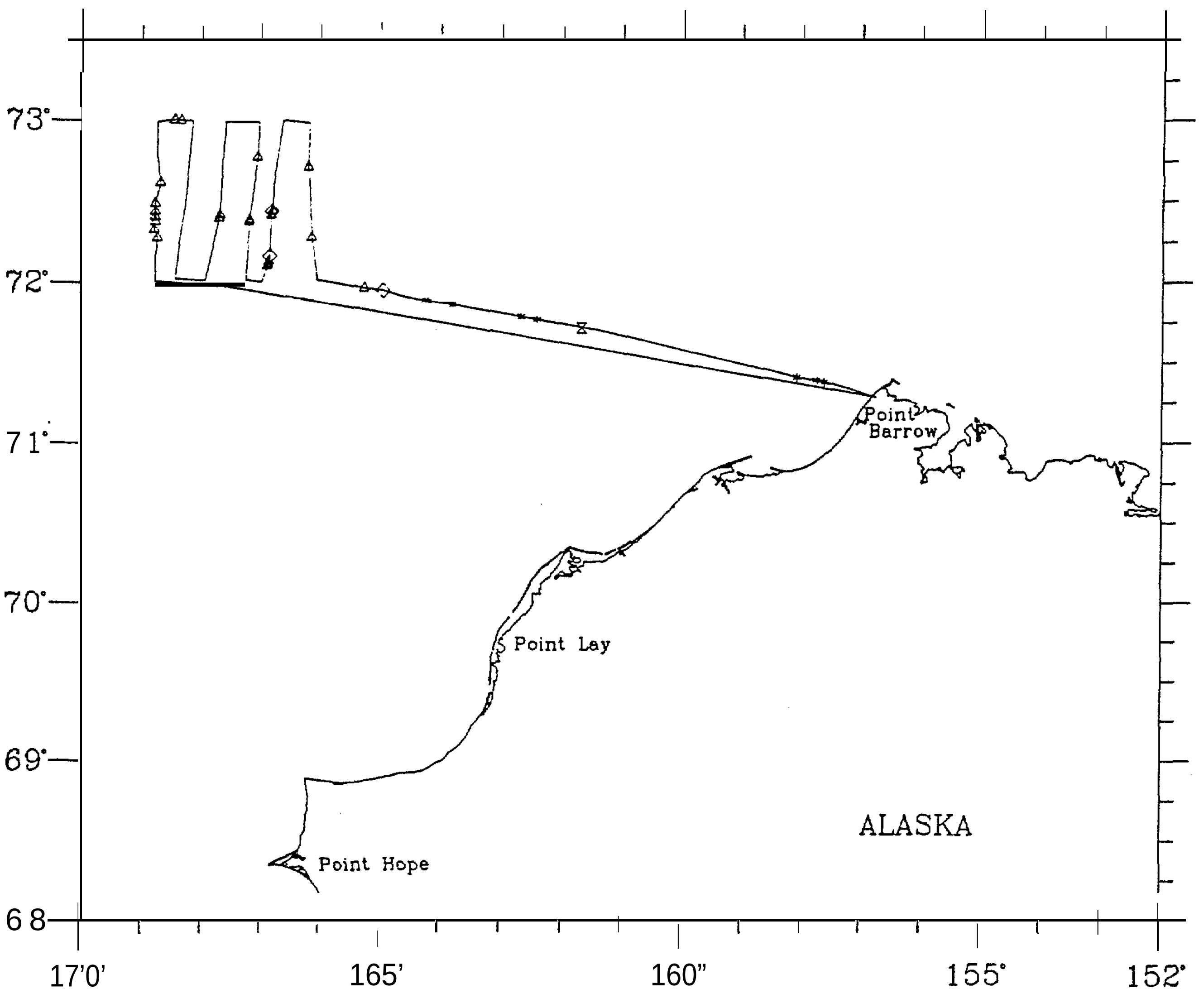
Bowhead Whale

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/1	71 '05.9	163037.6	2195	SP	Sw	230	0	2	42



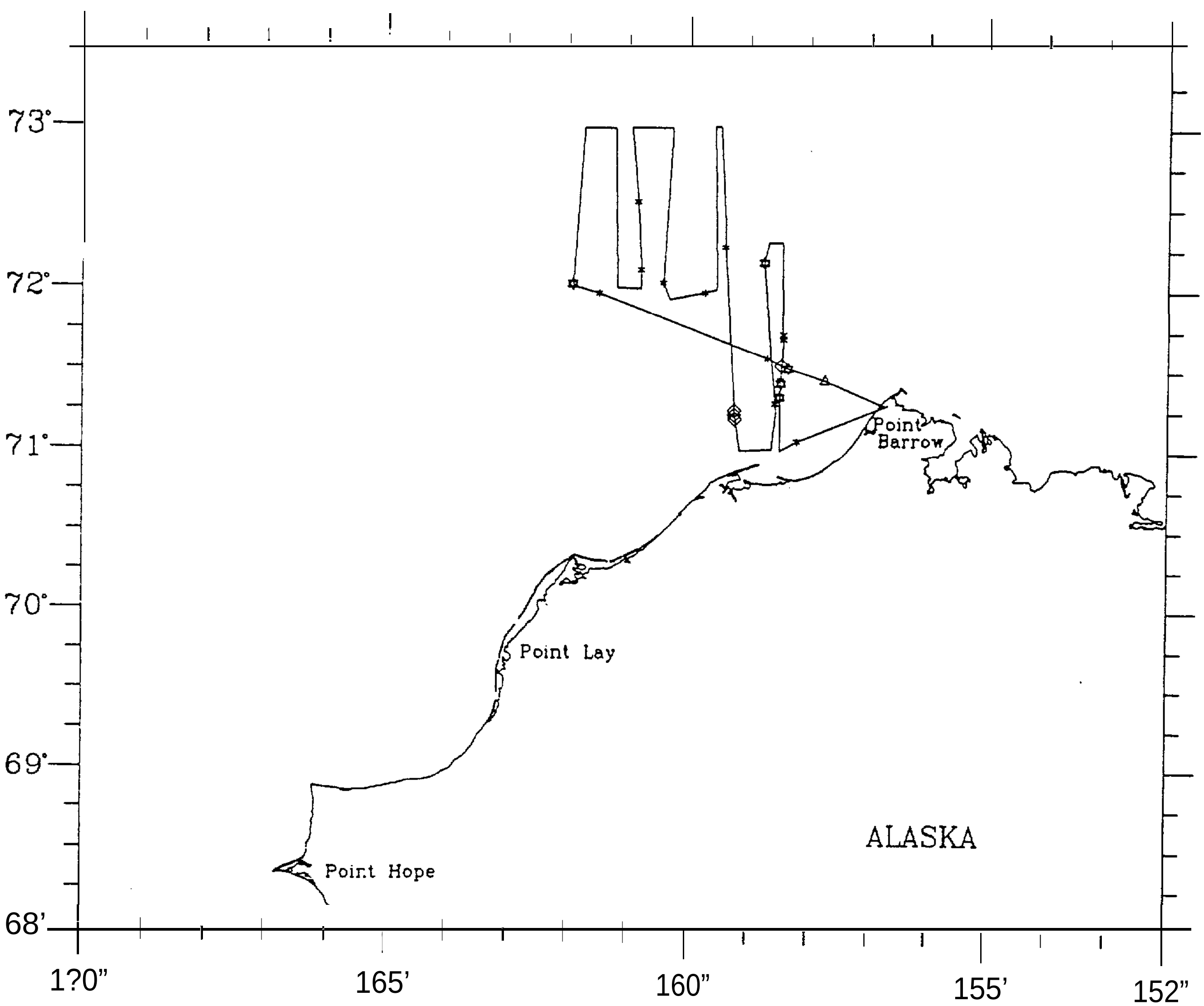
Flight 19: 14 October 1991

Flight was a transect survey in block 16N. Ice cover was 80-95% in block 13, 50-95% in northern blocks 14 and 15, and block 16N was ice-free. Weather was overcast with areas of precipitation and fog. Visibility ranged from 1-10 km, and sea state was Beaufort O-5. Belukhas, walruses, unidentified pinnipeds and a polar bear were seen.



Flight 20: 15 October 1991

Flight was a transect survey in portions of blocks 13, 13N and 14N. Ice cover was 90-99% north of 710 10'N, and 50-60% south of there. Weather was clear with a localized area of fog and low ceilings. Visibility was generally unlimited, and sea state was Beaufort O-1. Belukhas, walruses, bearded seals and unidentified pinnipeds were seen.

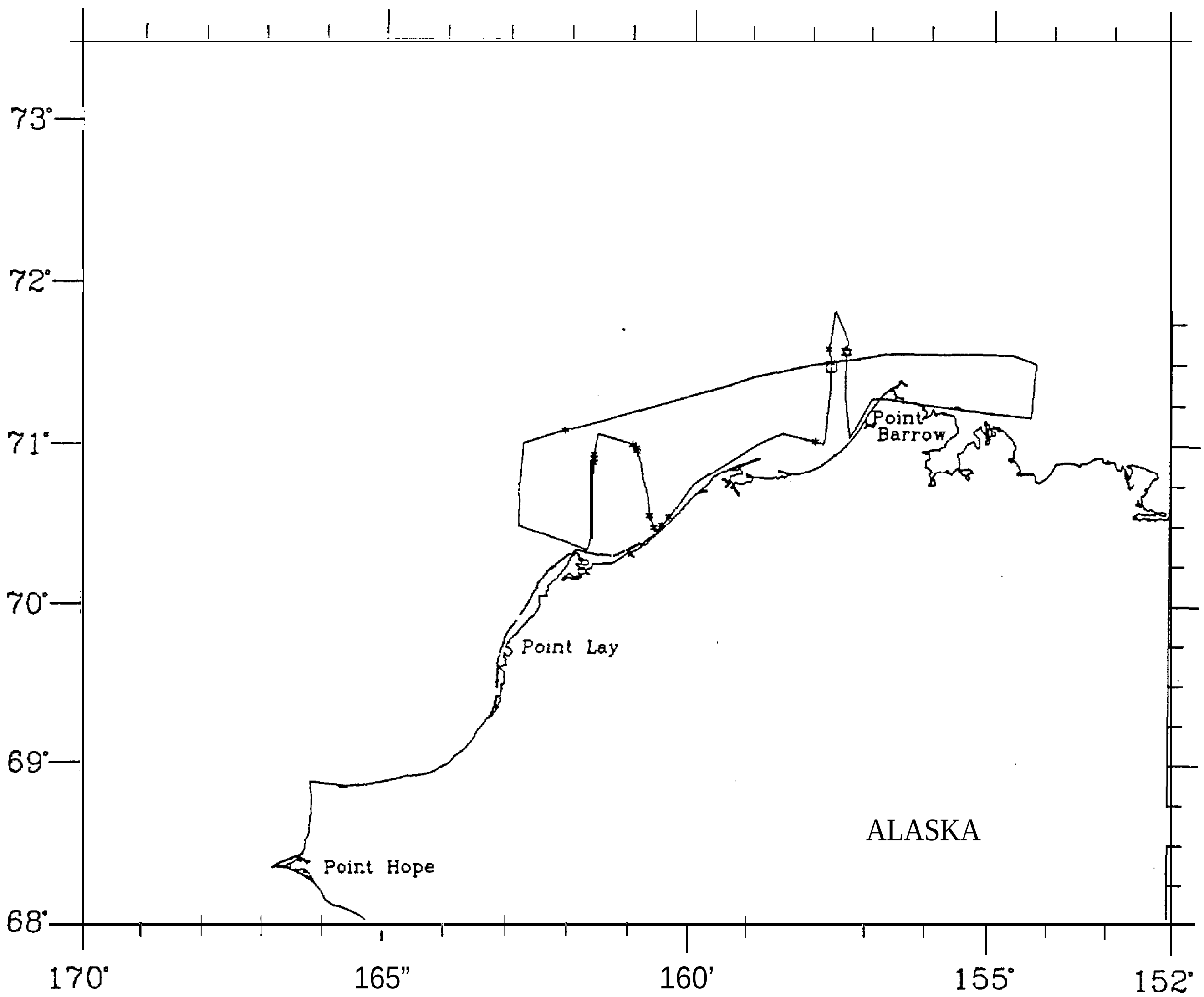


Flight 21: 16 October 1991

Flight was a transect and search survey in portions of blocks 12, 13 and 17. Ice cover was 75-99% in blocks 12 and 13, with 30-50% cover in northern block 17. Weather was fog with small areas of partly cloudy conditions. Visibility ranged from unacceptable to unlimited. Sea state was Beaufort O-5. One bowhead whale was seen swimming slowly. A bearded seal and unidentified pinnipeds were also seen.

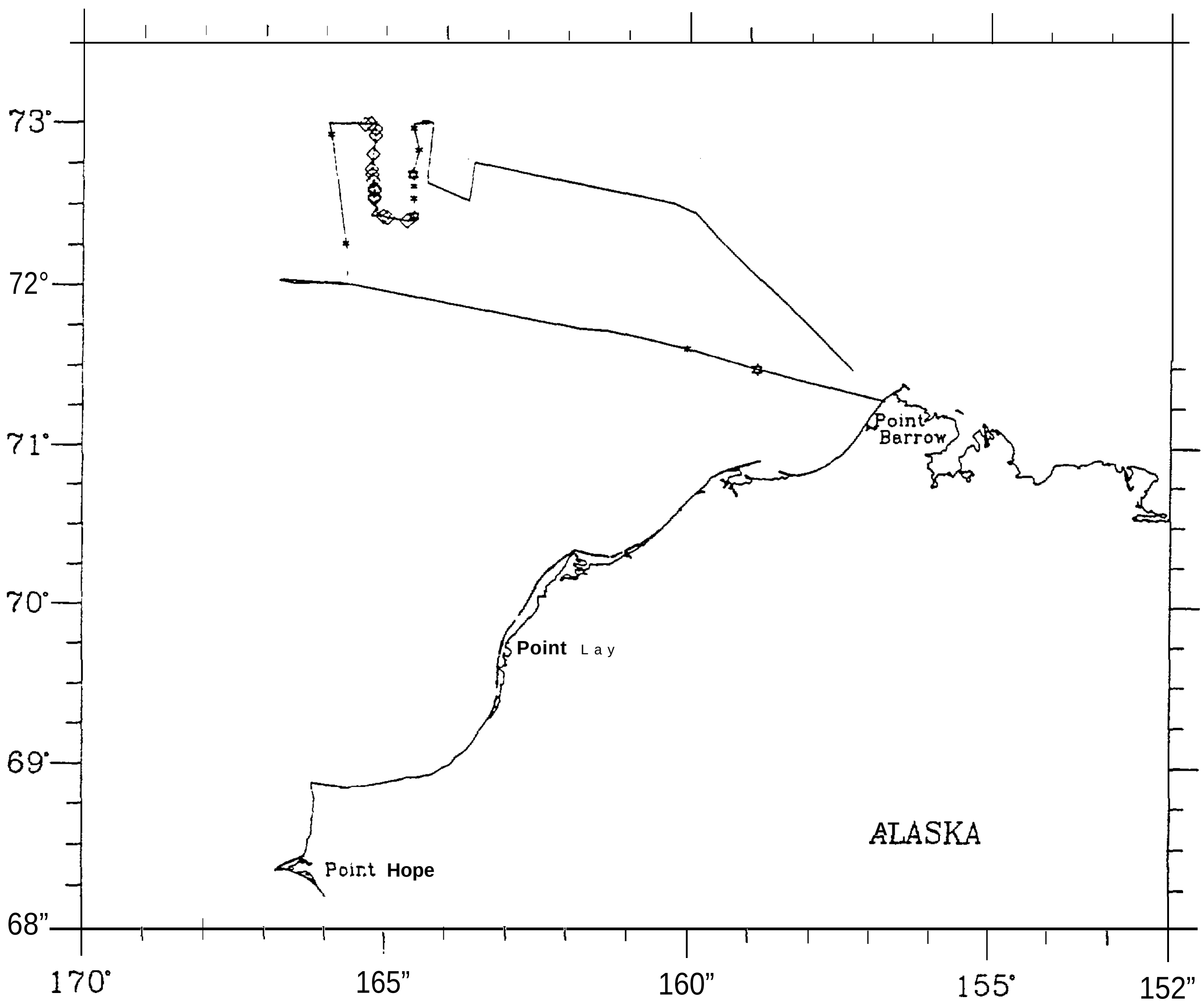
Bowhead Whale

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	m
1/0	71029.0	157038.4	933	BO	Sw	220	90	1	91



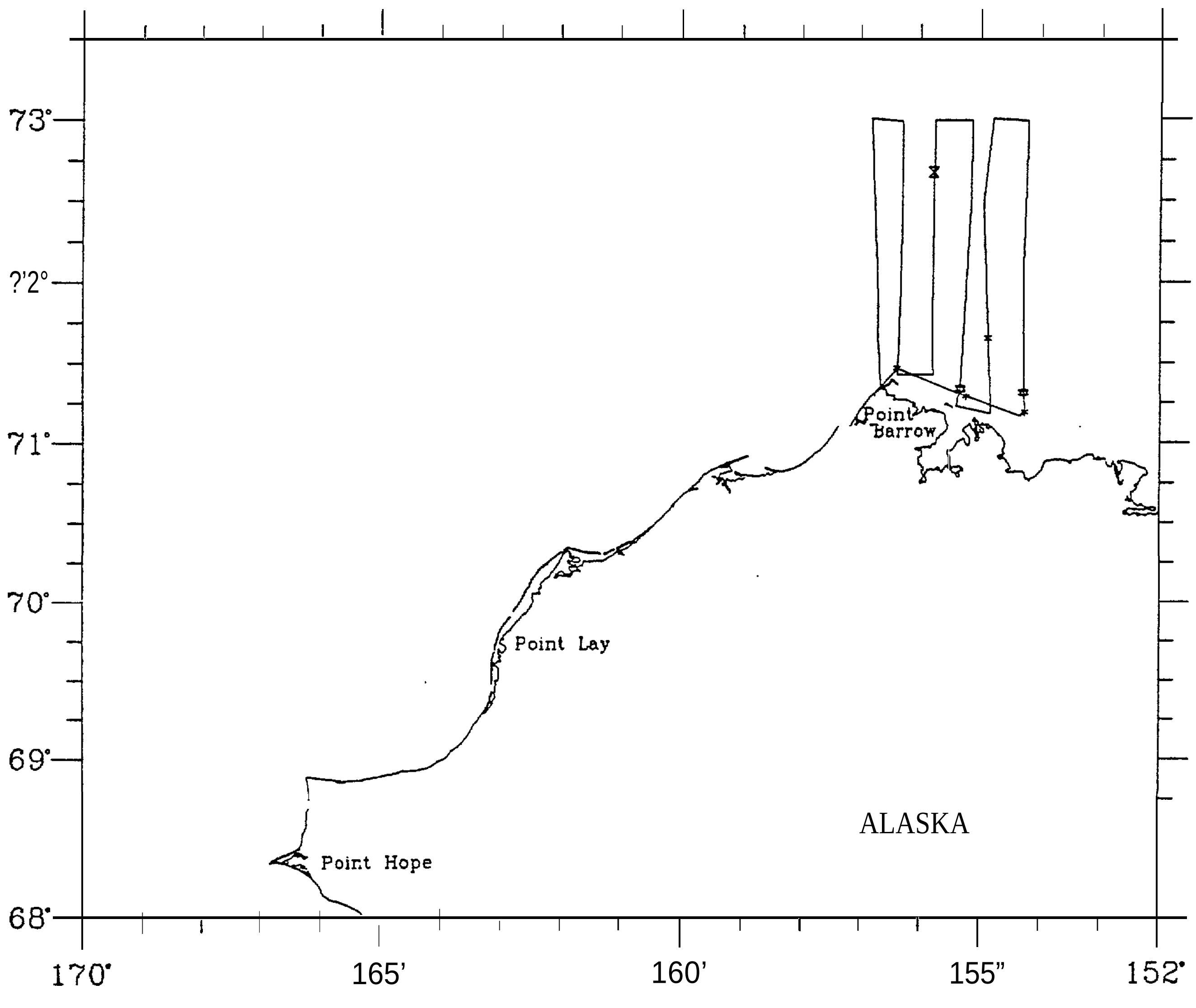
Flight 22: 17 October 1991

Flight was a transect survey in portions of block 15N. Ice cover was 50-95% everywhere but the southwest corner of 15N which was ice-free. Weather was low ceilings and fog, with 1-2 km visibility. Sea state was Beaufort O-5. Belukhas, walruses, bearded seals and unidentified pinnipeds were seen.



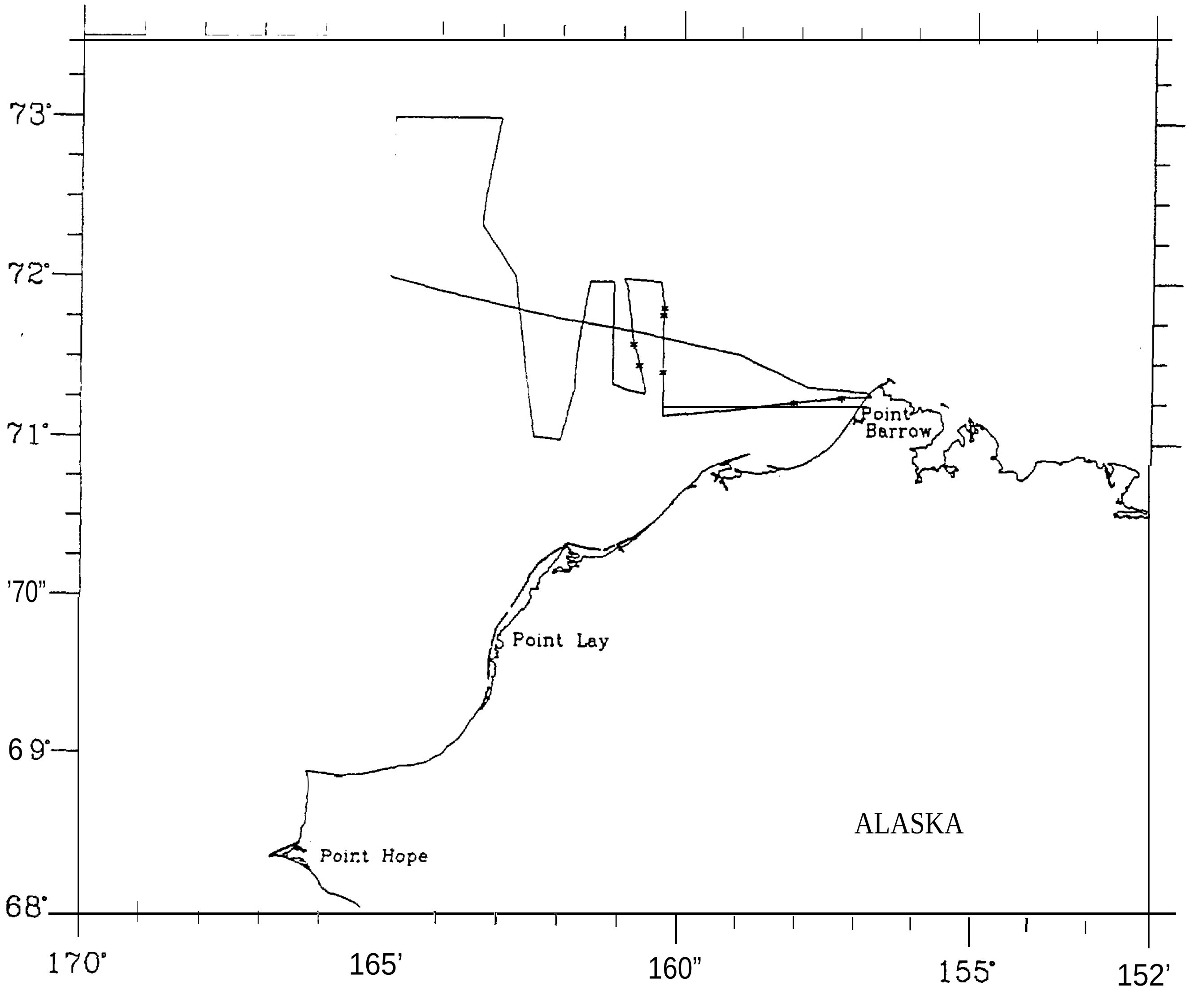
Flight 23: 20 October 1991

Flight was a transect survey in blocks 12 and 12N. Ice cover was 95-99%. Weather was clear with small patches of fog, and visibility was generally unlimited. Sea state was Beaufort O. One polar bear, bearded seals and unidentified pinnipeds were seen.



Flight 24: 22 October 1991

Flight was a transect survey in portions of blocks 14 and 15N. Ice cover was 85-90% in block 13, 65-i'0% in block 14 and block 15N was mostly ice-free. Weather was partly cloudy with some glare, and visibility ranged from 3 to 10 km. Sea state was generally Beaufort 1-2, with Beaufort 6-7 conditions curtailing survey effort south of710 N and west of 164050'W. Unidentified pinnipeds were seen.

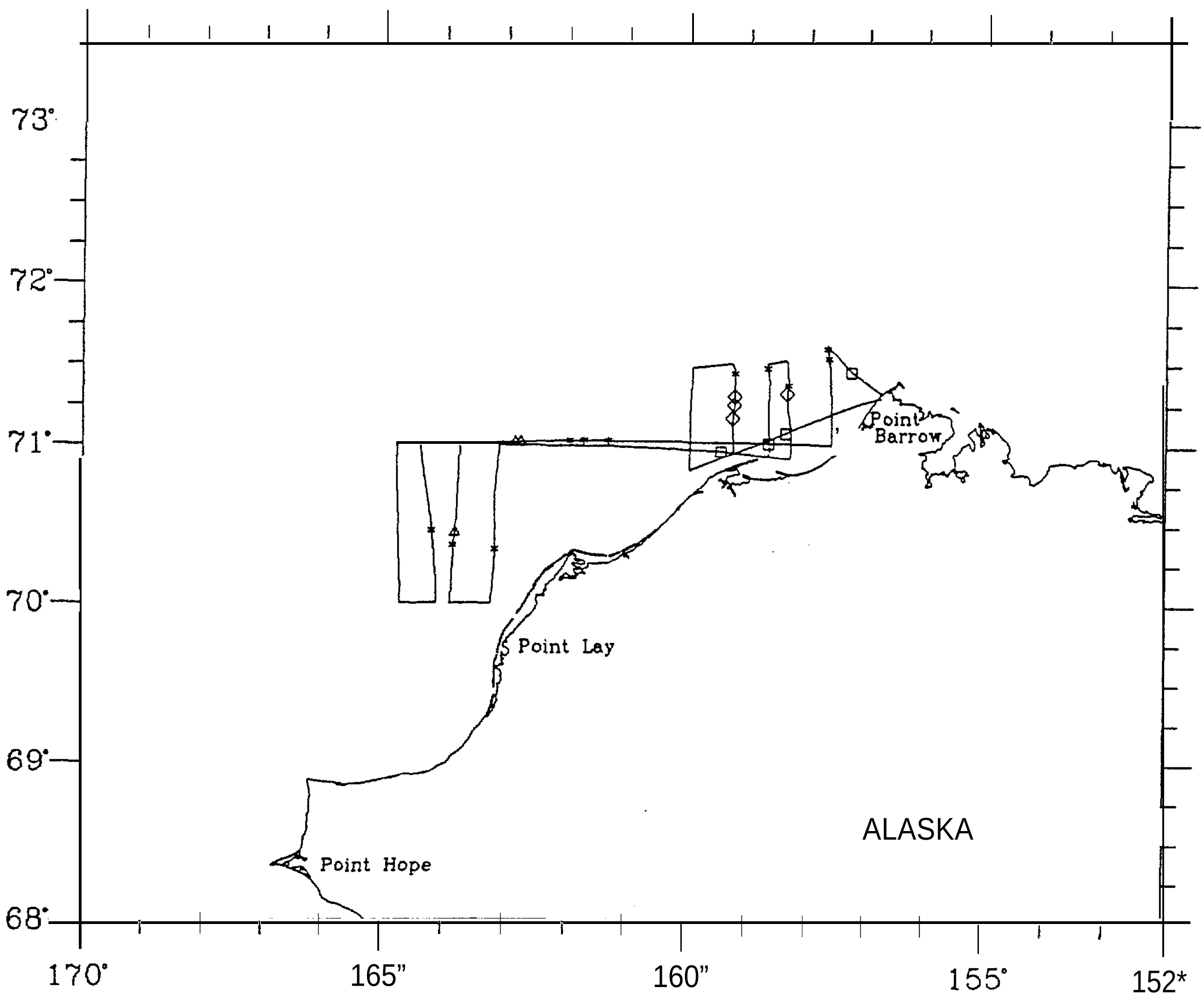


Flight 25: 23 October 1991

Flight was a transect survey in portions of blocks 13 and 18. Ice cover was 75-99% north of710 15'N, with open water south of there, Weather was overcast with fog, and visibility ranged from <1 -10 km. Sea state was Beaufort O-4. Five bowhead whales were seen; three of the whales were breaching. Belukhas, walruses and unidentified pinnipeds were also seen.

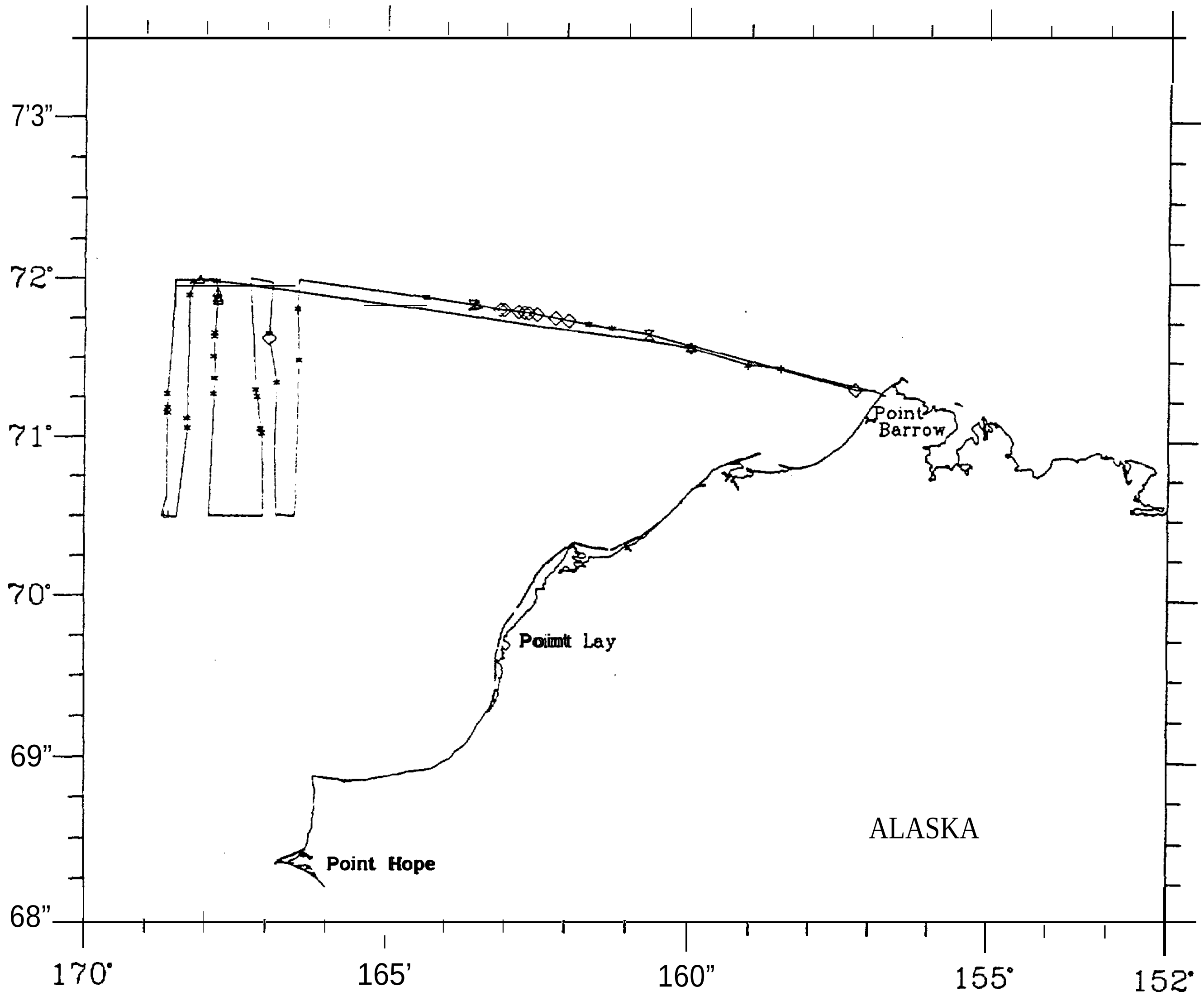
Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HOG	ICE	Ss	DEPTH
1/0	**71 "04.6**	**158"21.6**	**688**	SP	BR	---	0	3	20
1/0	**71"04,6**	**158"21.6**	**-**	SP	Sw	---	0	3	20
1/0	70057.8	159'26.1	2076	SP	BR	260	0	3	53
1/0	71 "00.9	158038.8	-	SP	BR	---	0	3	20
1/0	71027.1	157015.3	436	BO	Sw	250	70	1	123



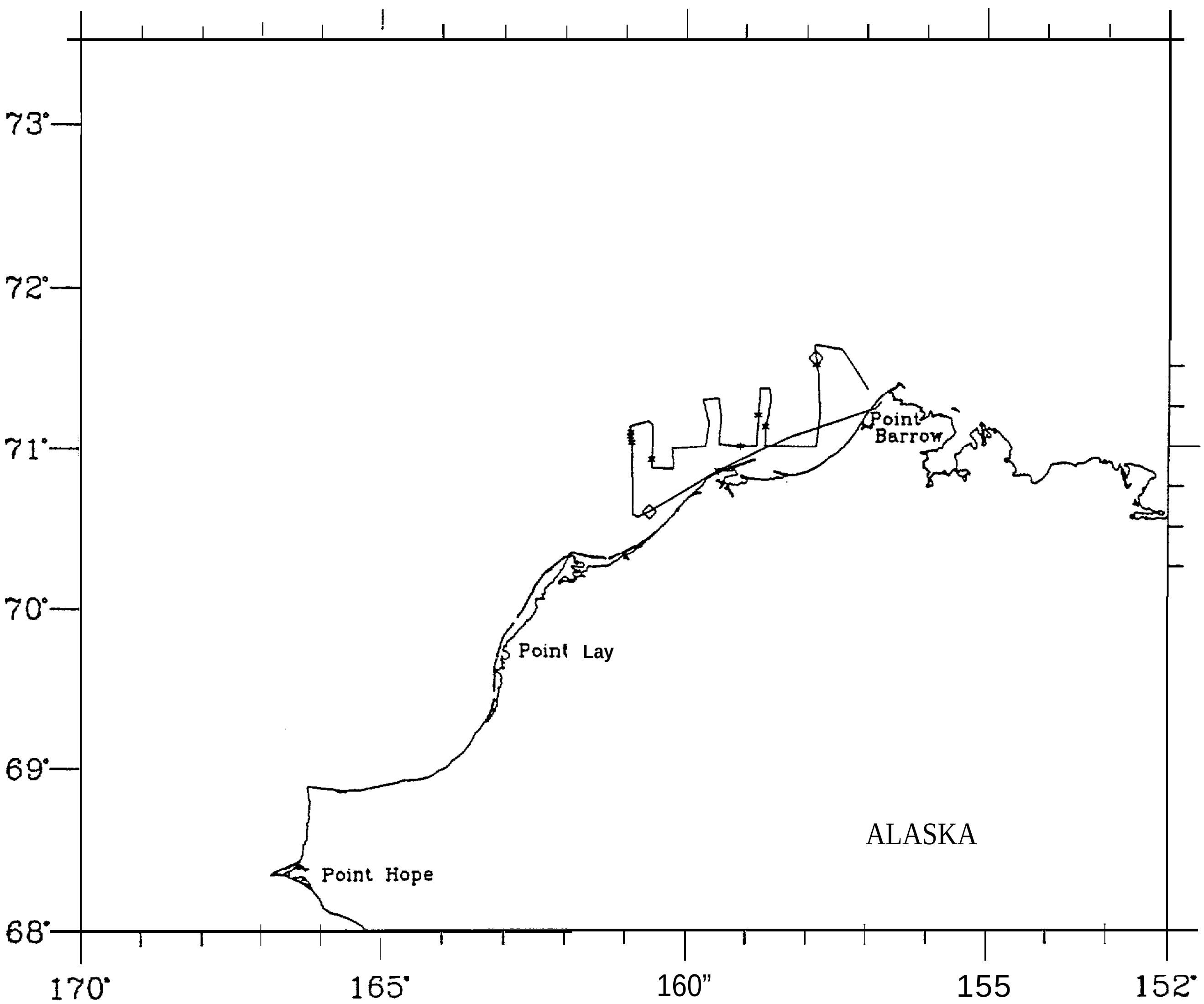
Flight 26: 24 October 1991

Flight was a transect survey in block 16 and the northern half of block 19. Ice cover was 65-90% in block 13, 10-70% in block 14 north of 71°30'N, and blocks 19, 16 and 15 were ice-free. Weather was overcast with areas of low ceilings and fog. Visibility ranged from < 1 to 10 km. Sea state was Beaufort O-4. Belukhas, walruses, a bearded seal, polar bears and unidentified pinnipeds were seen.



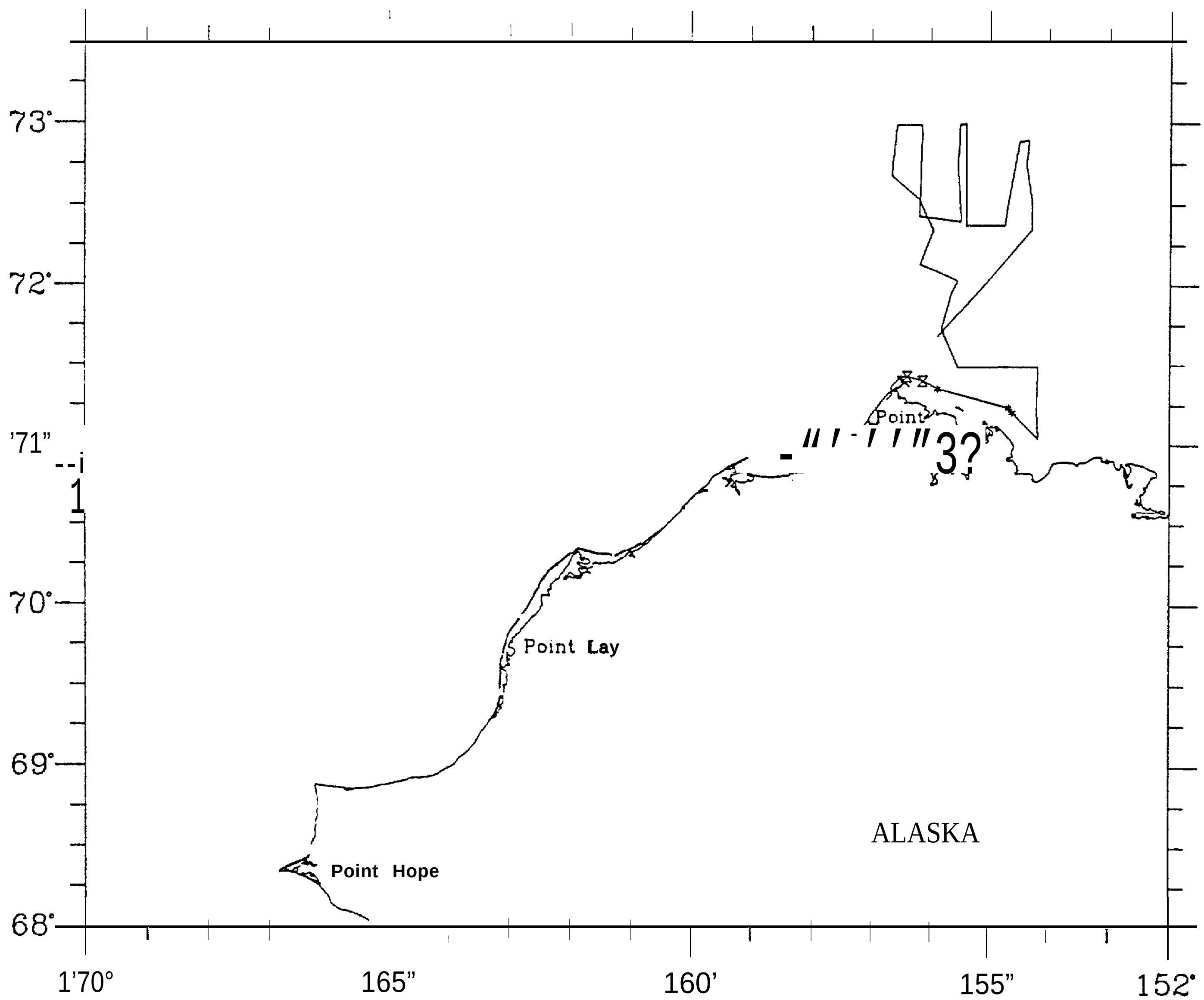
Flight 27: 25 October 1991

Flight was a transect survey in portions of blocks 13 and 17. Ice cover was 90-99% north of 71 °20'N, with generally ice-free conditions south of there. Weather was predominantly fog with localized areas of overcast. Visibility ranged from c 1 to '10 km, and sea state was Beaufort O-3. Walruses and unidentified pinnipeds were seen.



Flight 28: 28 October 1991

Flight was a transect survey in portions of blocks 12 and 12N. Ice cover was 90-99%. Weather was fog and low ceilings, and visibility ranged from unacceptable to 10 km. Sea state was Beaufort O-2. Polar bears and unidentified pinnipeds were seen.

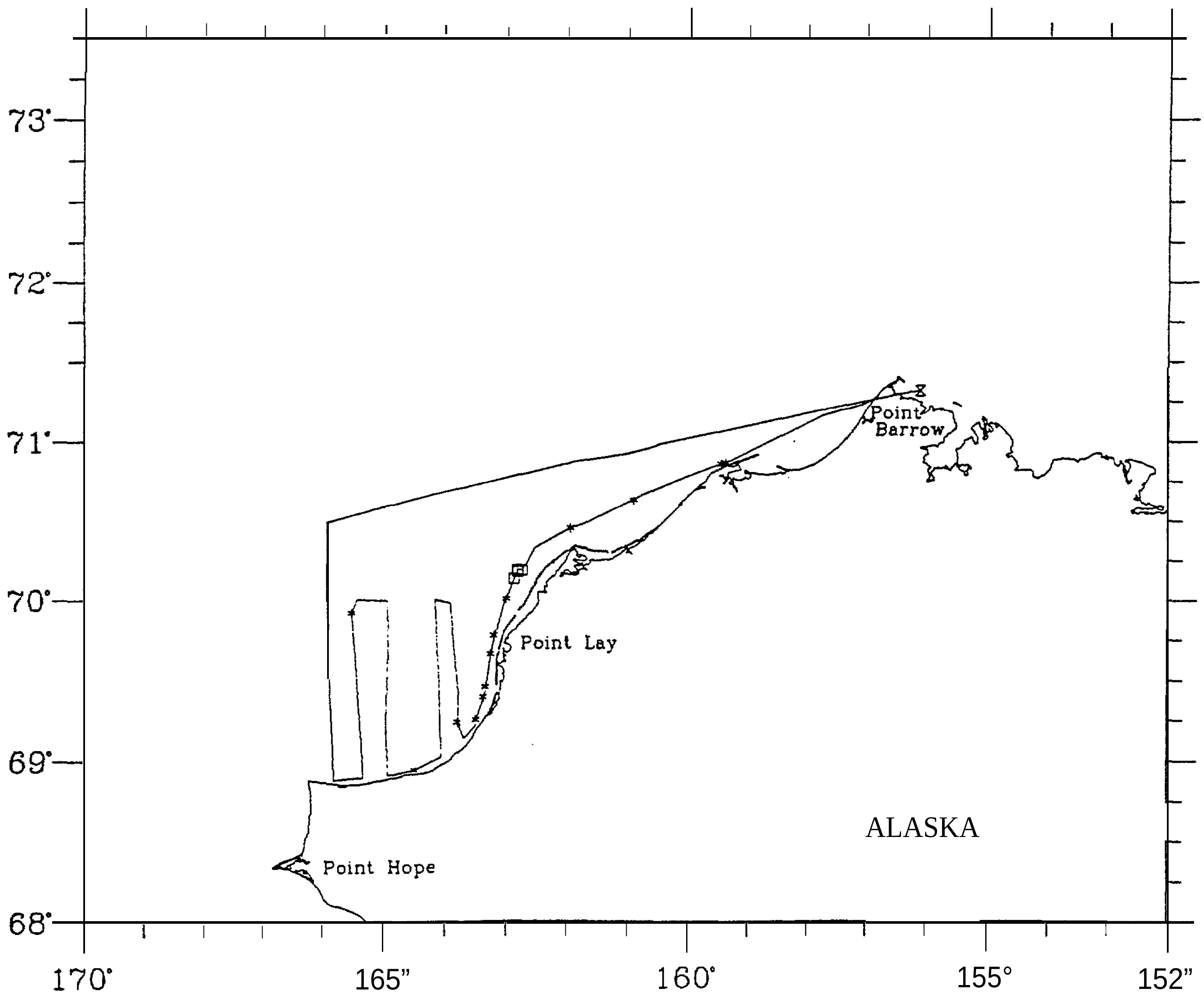


Flight 29: 31 October 1991

Flight was a **transect** survey in blocks 18 and 20. Ice cover was 25-50% north of 700 N latitude. Weather conditions were clear or partly cloudy, with glare affecting otherwise unlimited visibility. Sea state varied from Beaufort O-4. Four bowhead whales were seen nearshore in slushy new ice. Nine polar bears were seen at a bowhead whale carcass inshore of the barrier islands east of Pt. Barrow. Unidentified pinnipeds were also seen.

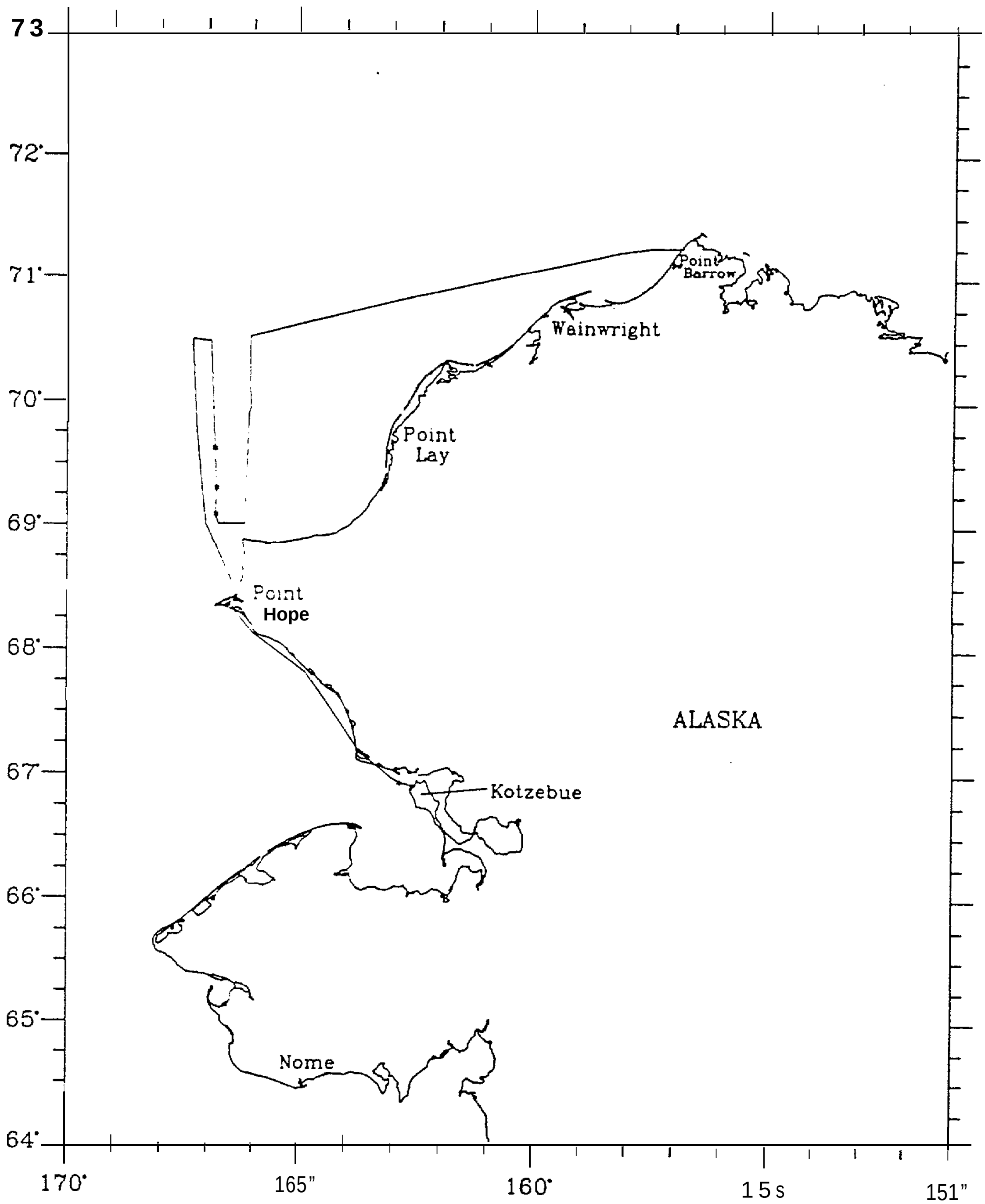
Bowhead Whales

T#/C#	LAT(N)	LONG(W)	DIS(M)	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70011.4	162043.9	-	BO	RE	180	40	1	15
1/0	70011.3	162048.3	-	BO	DI	---	40	1	15
1/0	70010.8	162"47.7	-	BO	RE	210	40	1	15
1/0	70008.1	162°51.5	1388	BL	SW	230	40	1	18



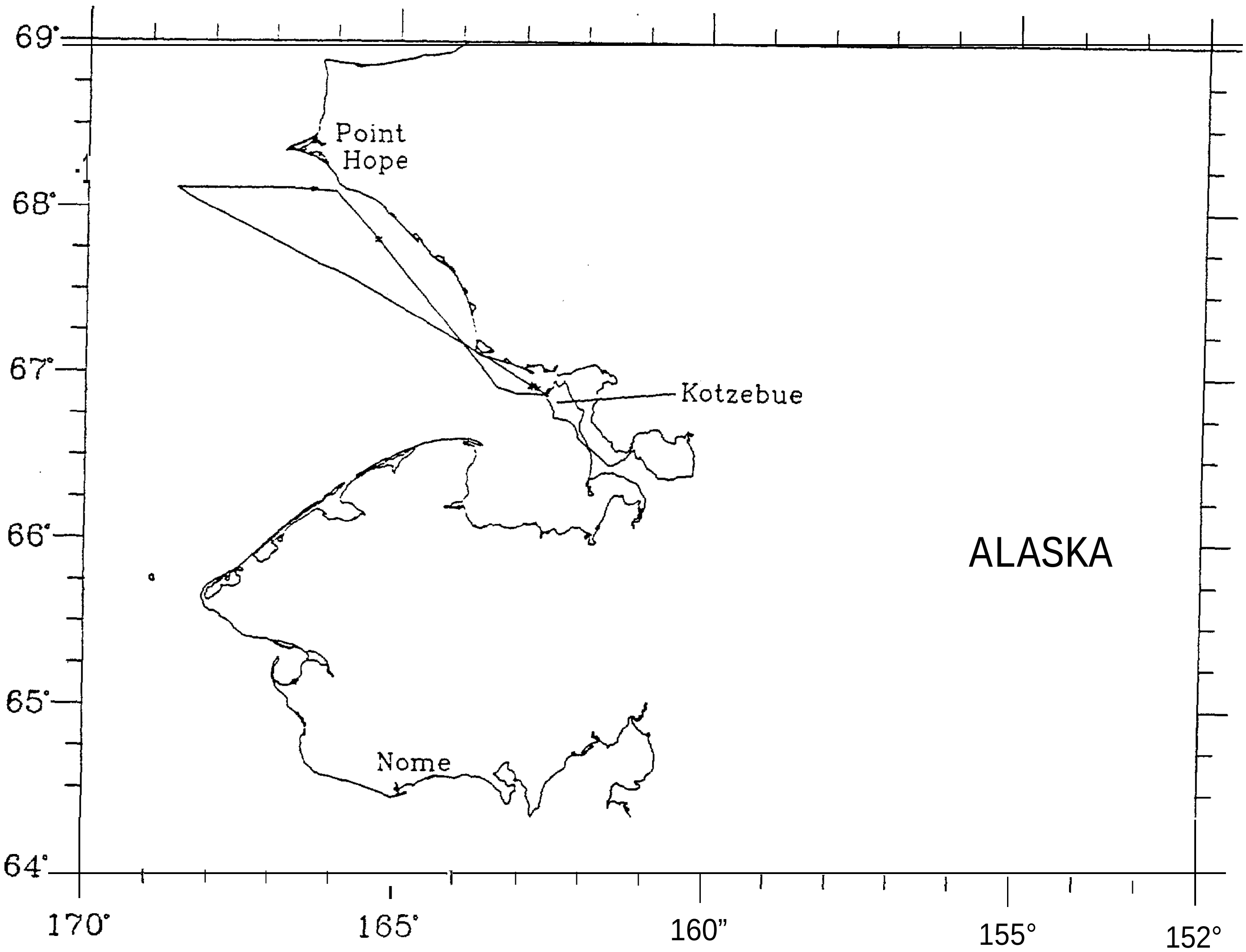
Flight 30: 1 November 1991

Flight was a transect survey in portions of blocks **19** and 21, with a search survey in portions of blocks 13, 22 and 31 enroute to Kotzebue. There was no ice south of 71 °30'N. Weather was partly cloudy with some glare, and visibility was 5 km to unlimited. Sea state ranged from Beaufort 2-7. Unidentified pinnipeds were seen.



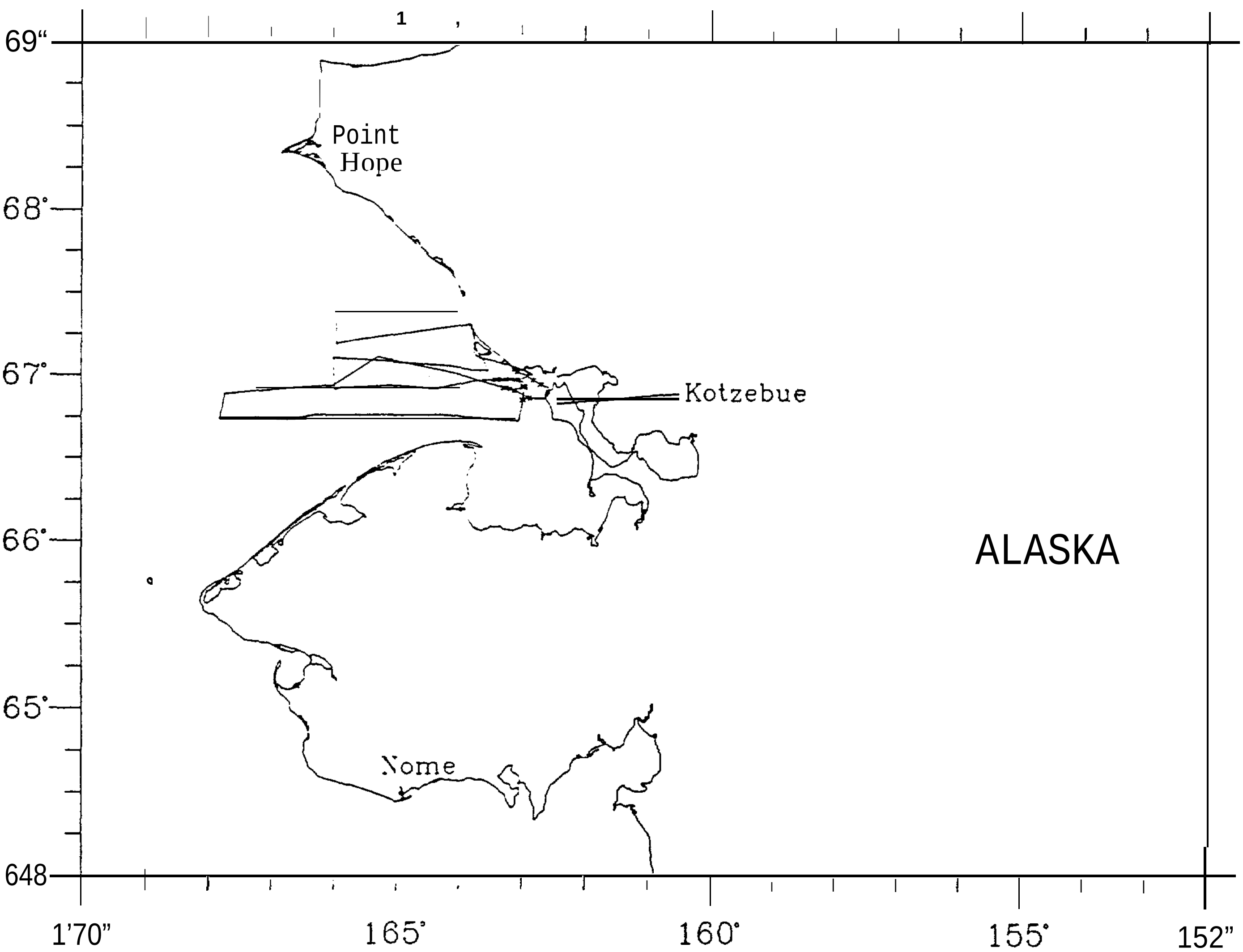
Flight 31: 2 November 1991

Flight was a transect survey in portions of block 22. There was 70% ice cover in Kotzebue Sound, but no ice west of there. Weather was clear, and glare severely reduced otherwise unlimited visibility. Sea state was Beaufort 3-6, with Beaufort 1 in Kotzebue Sound. Unidentified pinnipeds were seen.



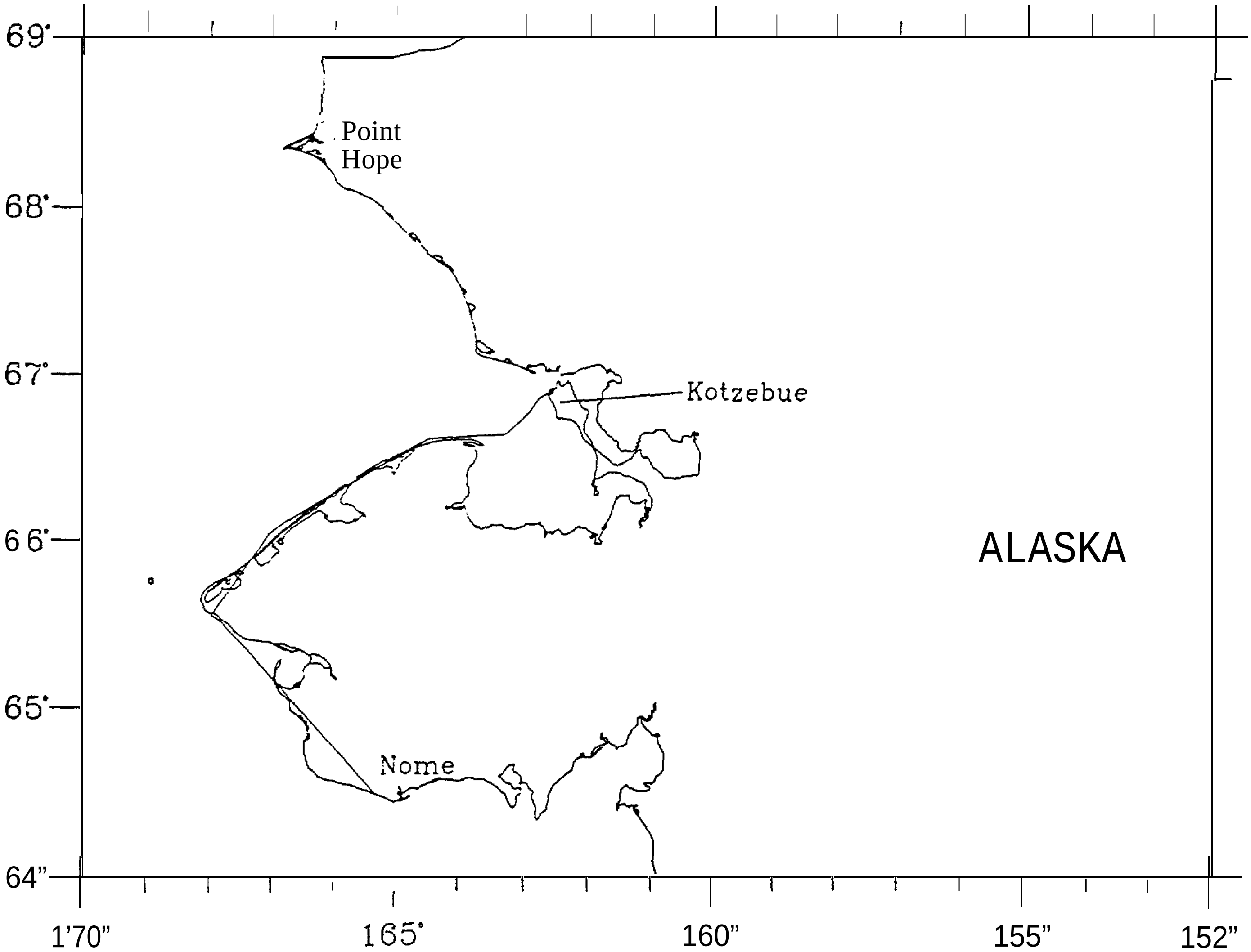
Flight 32: 5 November 1991

Flight was a transect survey in portions of blocks 24, 30 and 31. There was 50-90% new ice in Kotzebue Sound; all other areas were ice-free. Weather was clear, with unlimited visibility strongly affected by glare. Sea state ranged from Beaufort 1-7. Over 900 unidentified pinnipeds were seen hauled out on ice floes near Kotzebue.



Flight 33: 7 November 1991

Flight was a search survey through blocks 25, 28 and 31. Conditions were clear with unlimited visibility. Sea state was Beaufort 1-7. No marine mammals were seen.



APPENDIX B

ESTIMATES OF BOWHEAD AND GRAY WHALE DENSITY IN THE ALASKAN CHUKCHI AND WESTERN BEAUFORT SEAS, 1982-91

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INTRODUCTION

This appendix presents density estimates for bowhead and gray whales in the Alaskan Chukchi and western Beaufort seas for 1991, and for all years 1982-90 where data were available. Estimates are provided for the survey blocks in semi-monthly periods from 16 September through 31 October. Ideally, density estimates provide an evaluation of the relative importance of specific sampling units (i.e., survey blocks) to the population (Caughley 1977). Comparison of sequential density estimates can provide an index of a population's response to its environment over time.

The derivation of an population size estimate has not been a goal of this project. Therefore, density estimates presented here have not been adjusted to account for whales missed due to variability in sighting conditions or submergence. Also, density estimates were considered too small to stratify by environmental category (i. e., sea state, ice cover).

METHODS

Density Estimates

Density estimates were calculated for the study area survey blocks (Fig. B-1) using strip transect methods as described in Estes and Gilbert (1978):

$$D = \Sigma yi / \Sigma xi \qquad (1)$$

where D is the observed density of whales per unit area,

yi is the number of whales observed in the ith strip transect, and

xi is the area of the ith strip transect.

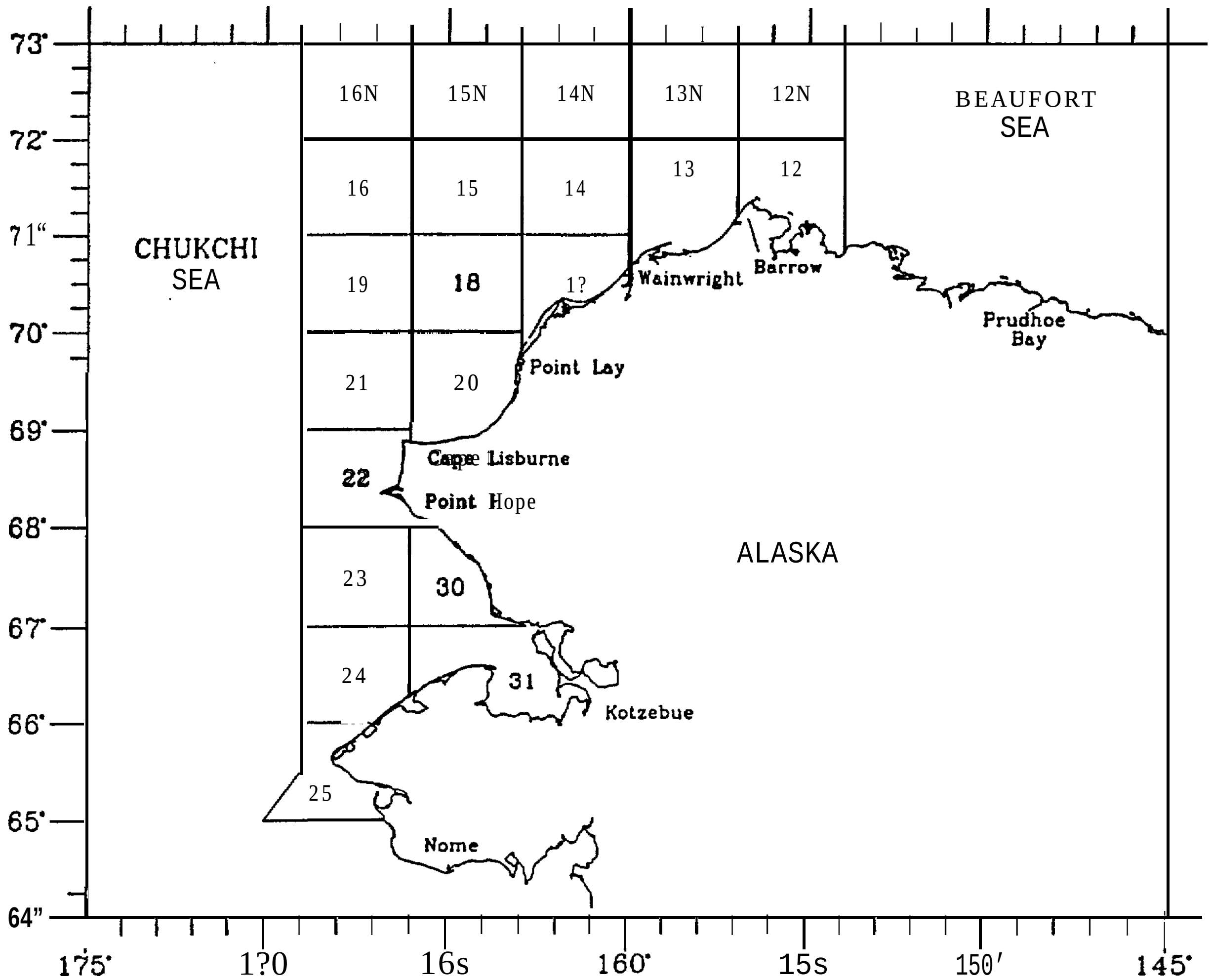


Figure B-l. Survey blocks for which bowhead and gray whale density estimates were calculated.

A 95% confidence interval was calculated for estimates when the number of sightings was > 1 using the equation:

$$C.I. = D \pm t_{0.05}(2)V\sqrt{V(D)} \qquad (2)$$

where Cl. is the confidence interval about the density estimate, and

$t_{0.05}(2)V$ is the critical value of t where alpha is 0.05 based on a two-tailed test with V degrees of freedom. Degrees of freedom equalled the total number of transects **minus one.**

Density estimates require that whale sightings are random (i.e., that sightings be made while surveying a random transect leg; see Fig. 3), and that they occur within a predetermined distance from the aircraft (Hayne 1949). A 2 km strip width (1 km on each side of the aircraft) was used to calculate density for both bowhead and gray whales, as in past years. This strip width is defensible based on histograms derived from the sighting distance database from which the estimates were calculated (Fig. B-2). Over 70% (n= 113) of all bowhead sightings, and nearly 59% (n= 70) of all gray whale sightings, were within 1 km of the aircraft during surveys of random transects. Thus, the strip from which density is calculated is the strip where the majority of whales are seen. However, the histograms also underscore the likelihood that some surfaced whales are missed within the 1 km strip, and that group size and behavior can affect the 'sightability' of surfaced whales. For example, both histograms have sighting peaks at distances >2.5 km that correspond to groups of feeding whales. In the case of bowheads, a group of 11 whales was seen feeding 2.9 km from the aircraft, Similarly, a group of 35 gray whales was identified at a distance of 5.2 km, probably due to the distinctive mud plumes associated with the whales.

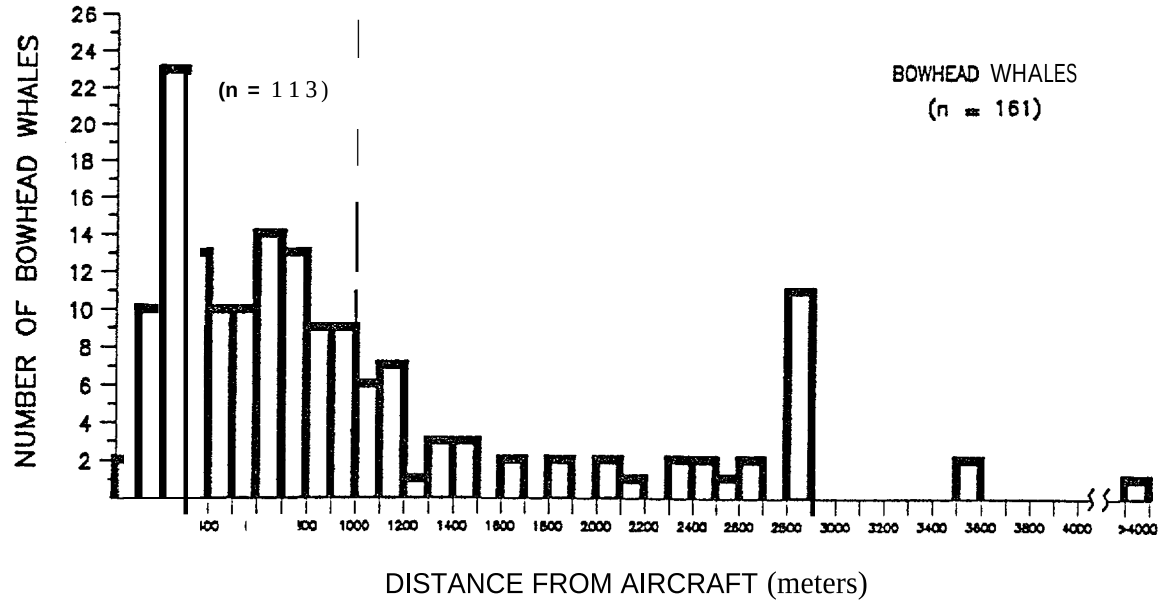
Statistics Presented in Tables

The parameters listed below were calculated for semi-monthly periods, mid-September through October, for each year 1982-91 that data were available for the Chukchi Sea study area. Surveys were conducted during the first week of November only in 1989-91, and results of these surveys are presented only in Table B-1,

Block Area (km*) - Areas were approximated by straight-line integration and are accurate to within about one percent of the true area.

Transect Distance (km) - Linear distance surveyed on transect legs.

Percent of Area Surveyed - The percent of area surveyed is a relative measure of survey effort expended per survey region. Strip width was defined as 2 kilometers (1 km on either side of the aircraft), therefore the number of square kilometers surveyed equalled twice the total number of kilometers flown. The percent of total area was calculated as total km^2 surveyed divided by the region area and multiplied by 100.



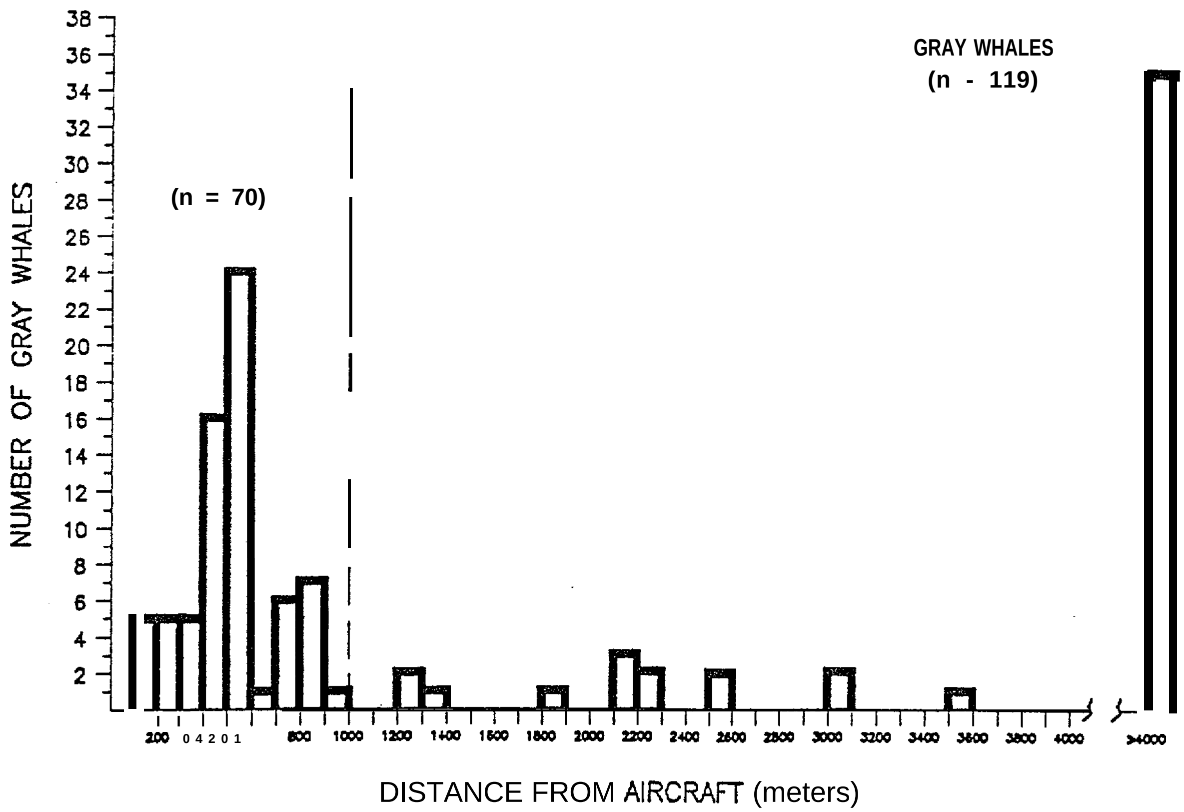


Figure B-2. Sighting distance histogram for bowhead whales and gray whales, from the cumulative 1982-91 data.

Transect time (h) - Time in hours spent on random transect survey legs.

No. Transects Flown - The total number of transect legs flown in a block; each leg or leg segment with random starting and ending points is counted as one transect leg.

No. Whales Observed - Number of bowhead or gray whales observed within 1 km of the aircraft while surveying a random transect leg.

Density (No./100 km^2) - Number of bowhead or gray whales per 100 square kilometers as calculated using equation (1].

A table summarizing density estimates and all other parameters noted above was prepared for each year 1982-91 where data were available. Tables are provided for bowheads even where no whales were seen within one km of the aircraft while on random transect to document transect survey effort conducted in each block for that time period. Conversely, tables for gray whales reflect only those periods when whales were seen within one km of the aircraft while on random transect. Cumulative (1982-91) estimates were derived for semi-monthly periods to provide an overall density index for each block. The cumulative estimates incorporate rounding errors inherent in the calculation of percent area surveyed and so are less precise than the annual estimates.

RESULTS

Results are presented by species beginning with 1991 and working backward to 1982. Annual summary tables for bowhead whales (Table B-1) and gray whales (Table B-3) are followed by a table of cumulative estimates (Tables B-2 and B-4) for each species. The reader should refer to Figure B-1 for the location of survey blocks.

Bowhead Whales

In 1991, highest bowhead densities were calculated for blocks 12 and 12N during the first half of October (Table B-1). Lower estimates were calculated for block 13 during the latter half of September and throughout October. There were no density estimates for the first week of November.

For years 1982-90, highest densities were most often calculated for blocks 12 and 13 (Table B-q). Exceptions include the relatively high density for block 15N during the first half of. October 1990, for blocks 13 and 18 during the first half of October 1988, block 17 during the latter half of September in 1983, and in block 14 during the latter half of October 1982.

Cumulative bowhead density estimates were highest in blocks 12,13 and 18 (Table B-2). Lower densities were calculated for blocks 12N, 14, 14N, 15N and 17. This overall pattern of relative density is similar to that of relative abundance summarized in the body of the report (see Table 16). Both indices of abundance reflect the dispersive nature of bowhead whale distribution in the northeastern Chukchi Sea in fall, as described in the body of the report.

Table B-1. **Annual semi-monthly estimates of bowhead whale densities, by survey** block, for each year 1982-91.

1991

Block No.	Block Area (km')	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)	Confidence Limits
16-30 SEP								
12	11163	742	13.30	3.03	10	0		
13	13673	1125	16.45	4.80	12	3	0.13	0. 00-0.32
14	11755	308	5.23	1.31	5	o		
12N	11453	311	5.43	1.27	5	0		
13N	11453	617	10.78	2.47	9	0		
14N	11453	439	7.67	1.73	4	0		
1-15 OCT								
12	11163	1018	18.23	4.31	17	6	0.29	0.03-0.52
13	13673	879	12.86	3.66	19	1	0s36	
14	11755	396	6.73	1.55	11	0		
15	11755	672	11.44	2.78	12	0		
17	9685	397	8.20	1,79	8	0		
18	12367	1098	17.75	457	12	0		
12N	11453	558	9.74	2.35	8	2	0.18	0s30-0s4
13N	11453	1160	20.26	4.79	15	0		
14N	11453	1036	18.09	4.24	11	0		
15N	11453	403	7.03	1.57	7	0		
16N	11453	667	11.64	2.78	7	0		
16-31 OCT								
12	11163	558	1000	2.30	8	0		
13	13673	703	10.29	3.02	12	1	0.07	
14	11755	494	840	1.91	8	0		
16	11755	662	11.27	2.63	6	0		
17	9685	201	4.15	0.81	6	0		
18	12367	499	8.07	1.95	7	0		
19	12367	334	5.39	1.32	6	0		
20	13088	660	10.08	2.58	6	0		
12N	11453	1014	17.71	4.10	12	0		
15N	11453	493	8.61	1.95	7	0		
1-7 NOV								
19	12367	168	2.71	0.66		0		
21	12975	331	5.10	1.29		0		
22	12712	108	1.71	0.37		0		
24	14031	156	2.22	0.59		0		
30	9014	288	6.40	1.20		0		
31	11559	241	4,17	0.89		0		

Table B-1. Annual semi-monthly estimates of bowhead whale densities, by survey block, for each year 1982-91 (Cent'd.).

1990

Block No.	Block Area (km^2)	transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./$100km^2$)	Confidence Limits
1-15 OCT								
12	11163	503	9.02	2.03	8	1	0.10	
13	13673	217	3.17	0.83	3	0		
16-31 OCT								
13	13673	267	3.90	1.06	6	0		
14	11755	553	9.40	2.15	8	0		
15	11755	334	5.69	1.35	5	0		
13N	11453	475	8.30	1,90	5	0		
14N	11453	438	7.65	1.65	5	0		
15N	11453	573	10.01	2.18	6	2	0.17	0.00-0.56
16N	11453	56	0.98	0.20	1	0		
1-7 NOV								
12	11163	103	1.85	0.41	2	0		
?3	13673	93	1,36	0.30	3	0		
14	11755	1	0.01	0.00	1	0		
15	11755	1	0.01	0.00	1	0		
18	12387	110	1.78	0,41	1	0		
21	12975	106	1.64	0.45	1	0		
22	12712	111	1.75	0.43	1	0		
23	14420	205	2.85	0.81	5	0		
30	9014	460	10.21	1.91	7	0		
31	11559	407	7.05	1.70	4	0		
12N	11453	647	11.29	2.65	6	0		
13N	11453	221	3.85	0.85	2	0		
14N	11453	220	3.84	0.90	2	0		

Table B-1. Annual semi-monthly estimates of bowhead whale densities, by survey block, for each year 1982-91 (Cent'd.).

1989

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)	Confidence Limits
16-30 SEP								
12	11163	525	9.41	2.39	11	0	0.00	
13	13673	702	10.27	2.85	8	0	0.00	
15	11755	113	1.92	0.32	3	0	0.00	
18	12367	129	2.08	060	2	0	0.00	
12N	11453	980	17.11	4,12	10	0	0.00	
13N	11453	650	11,35	2.75	6	0	0.00	
14N	11453	691	12.07	3.02	6	1	0.07	
15N	11453	774	13.52	3.36	7	1	0.06	
16N	11453	662	11.56	2.74	6	0	0.00	
1-15 OCT								
14	11755	678	11.54	2.77	13	0	0.00	
15	11755	226	3.85	0.94	4	0	0.00	
17	9685	562	11.60	2.08	10	0	0.00	
13N	11453	221	386	0.91	2	0	0.00	
14N	11453	688	12.02	3.11	9	0	0.00	
15N	11453	677	11.82	2.69	7	0	0.00	
16-31 OCT								
13	13673	1228	17,96	5.49	17	6	0.24	0.00-0.43
14	11755	146	2.48	0.64	6	0	0s30	
15	11755	409	6.96	1.70	9	0	0.00	
16	11755	640	10.88	2.67	6	0	0.00	
17	9685	295	6.09	1,3	4	0	0.00	
18	12367	783	12,67	3.38	14	0	0.00	
20	13088	404	6.17	1.79	5	0	0.00	
22	12712	746	11.74	3.10	8	0	0.00	
23	14420	516	7,16	2.16	5	0	0.00	
30	9014	43	0.95	0.16	2	0	0.00	
13N	11453	660	11.52	2.74	7	0	0.00	
15N	11453	632	11,03	2.92	7	1	0.08	
1-3 NOV								
23	14420	251	3.48	1.00		0	0.00	
24	14031	540	7.70	2.22		0	0.00	
25	10930	131	2.39	0.53		0	0.00	

Table B-1. Annual semi-monthly estimates of bowhead whale densities, by survey block, for each year 1982-91 (Cent'd).

1988

Block No.	Block Area (km')	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)	Confidence Limits
1-15 OCT								
12	11163	343	6.15	1.29	6	0	0.00	
13	13673	723	10.58	3.59	15	4	0.28	0.004.56
14	11755	667	11.34	2.78	10	1	0.08	
15	1 1755	558	9.49	2.10	12	0	0.00	
16	11755	661	11.25	2.55	9	0	0.00	
17	9685	255	5.27	1.19	6	0	0.00	
18	12367	746	12.07	3.56	8	10	0.67	0.00-0.22
19	12367	162	2.63	0.69	4	0	0.00	
12N	11453	555	9.70	2.61	8	0	0.00	
13N	11453	765	13.36	2.80	7	0	0.00	
?4N	11453	482	8.42	2.19	5	0	0.00	
15N	11453	683	1 1.92	2.89	10	0	0.00	
16N	11453	775	13.54	3.33	10	0	0.00	

Table B-1. Annual semi-monthly estimates of bowhead whale densities, by survey block, for each year 1982-91 (Cent'd).

1987

Block No.	Block Area (km²)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)	Confidence Limits
16-30 SEP								
12	11163	977	17s0	4.05	16	1	0.05	
13	13673	1424	20.82	5.84	13	1	0.04	
14	11755	658	11.20	2.58	7	0	0.00	
15	11755	550	9.36	2.22	7	0	0.00	
16	11755	109	1 .s5	0.38	1	0	0.00	
17	9685	418	8.64	1.71	7	0	0.00	
18	12367	664	10.73	2.80	9	0	0.00	
20	1308a	114	1.74	0.47	4	0	0.00	
22	12712	302	4.75	1.27	6	0	0.00	
12N	11453	533	9.31	2.25	10	1	0.09	
13N	11453	353	6.17	1.37	9	0	0.00	
1-15 OCT								
12	11163	477	8S4	1.91	9	0	0.00	
13	13673		15.00	4.18	10	0	0.00	
14	11755	42%	7.44	1.82	6	0	0.00	
17	9685	112	2.31	0.47	2	0	0.00	
12N	11453	669	11.68	2.83	8	0	0.00	
13N	11453	220	3.84	0.92	6	0	0.00	
16-31 OCT								
12	11163	1083	19.40	4.39	16	3	0.14	0.00-0.32
13	13673	568	8.32	2.27	5	1	0.09	
17	9685	443	9.15	1.91	6	0	0.00	
18	2367	110	1.78	0.42	1	0	0.00	
12N	11453	8.58	14.99	3.45	13	0	0.00	
13N	11453	519	9.06	2.02	6	0	0.00	

Table B-1. **Annual semi-monthly estimates of bowhead whale densities, by survey block,** for each year 1982-91 (Cent'd).

1986

Block No.	Block Area (km²)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)	Confidence Limits
16-30 SEP								
12	11163	566	10.14	2.23	8	0	0.00	
13	13673	1205	17.63	4.99	11	0	0.00	
14	?1755	679	11.55	2.95	6	1	0.07	
15	11755	472	8.03	1.80	6	0	0.00	
17	9685	453	9.35	1.69	7	0	0.00	
18	12367	170	2.76	0.70	2	0	0.00	
t-15 OCT								
?2	11163	1025	18.37	4.42	15	4	020	0.00-0.41
13	13673	1118	16.35	4.53	15	0	0.00	
14	11755	1150	19.56	4.58	18	0	0.00	
17	9635	742	15.32	3.15	12	0	0.00	
18	12367	398	6.43	1.55	5	0	0.00	
12N	11453	8	0.14	0.03	5	0	0.00	
13N	11453	192	3.36	0.73	9	0	0.00	
16-31 OCT								
12	11163	529	9.48	2.13	6	0	0.00	
13	13673	910	13.31	3.77	13	0	0.00	
17	9685	532	10.99	2.19	8	0	0.00	
18	12367	110	1.78	0.53	1	0	0.00	

Table B-1. Annual semi-monthly estimates of bowhead whale densities, by survey block, for each year 1982-91 (Cent'd).

1985

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)	Confidence Limits
16-30 SEP								
12	11163	536	9.61	2.25	6	0	0.00	
1-15 OCT								
12	11163	896	16.06	3.85	10	3	017	0.00-0.41
15	11755	7	0.11	0.03	5	0	0.00	
17	9685	426	8.80	1.74	6	0	0.00	
18	12367	556	9.00	2.22	9	0	0.00	
16-31 OCT								
12	11163	1088	19.50	4.57	12	1	0.05	
13	13673	702	10.26	2.93	6	0	0.03	

Table B-1. Annual semi-monthly estimates of bowhead whale densities, by survey block, for each year 1982-91 (Cent'd).

1984

Block No.	Block Area (km')	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)	Confidence Limits
16-30 SEP								
12	11163	546	9.78	2.45	7	3	0.27	0.00-0.71
13	13673	744	10.88	2.93	8	2	0.13	0.00-0.40
14	11755	548	9.32	2.03	5	0	0.00	
17	9685	157	3.25	0.64	4	0	0.00	
1-15 OCT								
12	11163	921	16.50	3.59	12	13	0.71	0.050.96
13	13673	472	6.90	2.01	5	3	0.32	0. 00-0.92
17	9685	409	8.45	1.59	5	0	0.00	
12N	11453	6	0.11	0.03	3	o	0.00	
16-31 OCT								
t2	11163	1353	24.24	5.45	18	6	0.22	0.03-0.39
t3	13673	432	6.31	1.76	9	0	0.00	

Table B-1. Annual semi-monthly estimates of bowhead whale densities, by survey block, for each year 1982-91 (Cent'd).

1983

Block No.	Block Area (km²)	Transact Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)	Confidence Limits
16-30 SEP								
12	11163	1161	20.80	4.64	20	5	0.22	0.00-0.40
13	13673	418	6.11	1.73	5	2	0.24	0.00-0.82
14	11755	148	2.51	0s8	3	0	0.00	
17	9685	?22	2.52	0s4	4	2	0.82	0.00-0.22
t-15 OCT								
12	11163	1510	27.05	5.78	19	4	0.13	0.00-0.27
13	13673	434	6.35	1.66	4	0	0.00	
14	11755	113	1.92	0.53	4	0	0.00	
15	11755	774	13.16	3.07	7	0	0.00	
17	9685	450	9.30	1.66	6	0	0.00	
18	12367	115	1.86	0.55	2	0	0.00	
22	12712	626	9.84	2.19	8	0	0.00	
12N	11453	15	.26	.06	7	0	0.00	
15N	11453	112	1.95	0.41	3	0	0.00	
16-31 OCT								
12	11163	444	7.95	1.86	6	0	0.00	
13	13673	456	667	1.72	4	0	000	
14	11755	220	3.74	0.83	2	0	0.00	
18	12367	662	10.71	2.61	9	0	0.00	
20	13088	488	7,46	1.92	8	0	0.00	
21	12975	315	4.85	1.22	3	0	0.00	

Table B-1. Annual semi-monthly estimates of bowhead whale densities, by survey block, for each year 1982-91 (Cont'd).

1982

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)	Confidence Limits
16-30 SEP								
12	11163	695	12.45	2.67	10	3	0.22	0.00-0.53
1-15 OCT								
12	?1163	1036	18.55	3.88	17	5	0.24	0.00-0.46
13	13673	653	9.55	2.47	11	10	0.77	0.00-0.22
14	11755	276	4.70	1.17	8	0	0.00	
17	9685	752	15.52	2.79	18	0	0.00	
?8	12387	378	6.11	1.29	8	0	0.00	
20	13088	863	13.19	3.23	9	0	0.00	
21	12975	238	3.67	0.89	6	0	0.00	
16-31 OCT								
12	11163	386	6.92	1.51		0	000	
13	13673	189	2.76	0.72		0	0.00	
14	11755	98	1.66	0.41		1	0.51	

Table B-2. Cumulative (1982-91) semi-monthly estimates of bowhead whale densities, by survey block.

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transacts Flown	No. Whales Observed	Density (No./100km^2)	Confidence Limits
16-30 SEP								
12	11163	5749	103.00	23.70	88	12	0.10	0.00-0.14
13	13673	5817	82.17	23.15	57	8	0.07	0.00-0.11
14	11755	2344	39.88	9.50	29	1	0.02	
15	11755	1135	19.30	4.34	16	0	0.00	
16	11755	111	1.90	0.40	3	0	0.00	
17	9685	1150	23.76	4.78	22	2	0.09	0.00-0.23
18	12367	962	15.56	3.90	13	0	0.00	
20	13088	114	1.74	0.47	4	0	0.00	
22	12712	302	4.75	1.27	6	0	0.00	
12N	11453	1842	32.17	7.72	40	1	0.03	
13N	11453	1624	28.36	6.61	29	0	0.00	
14N	11453	1136	19.84	4.78	15	1	0.04	
15N	11453	777	13,56	3.37	9	1	0.08	
16N	11453	662	11.56	2,74	6	0	0.00	
?-15 OCT								
12	1116-3	7729	138.48	31.06	113	36	0.23	0.05-0.21
13	13673	5522	80.78	22.93	83	18	0.16	0.00-0.19
14	11755	3723	63.34	15.25	75	1	0.01	
15	11755	2238	38.07	8.92	41	0	0.00	
16	11755	662	11.26	2.55	10	0	0.00	
17	9885	4105	84.77	16,45	73	0	0.00	
18	12367	3293	53.25	13,76	46	10	0.15	0.00-0.21
19	12367	162	2.63	0.69	4	0	0.00	
20	13088	866	13.23	3.24	14	0	0.00	
21	12975	238	3.67	0.89	6	0	0.00	
22	12712	626	9.84	2.19	8	0	0.00	
12N	11453	1816	31.71	7.91	44	2	0.06	0.00-0.14
13N	11453	2562	44.73	10,17	42	0	0.00	
1 UN	11453	2209	38.58	9.55	28	0	0.00	
15N	11453	1873	32.71	7.57	27	0	0.00	
16N	11453	1442	25.18	6.11	17	0	0.00	
16-30 OCT								
12	11163	5445	9755	22.20	73	10	0.09	0.00-0.13
13	13673	5455	79.79	22.75	74	8	0.07	O.wo.11
14	11755	1513	25.73	595	31	1	0.03	
15	11755	749	12.74	3.07	19	0	0.00	
16	11755	1302	22.15	5.30	12	0	0.00	
17	9685	1471	30.37	6.21	24	0	0.00	
18	12367	2166	35.03	8.89	33	0	0.00	
19	12367	335	5.42	1.33	7	0	0.00	
20	13088	1552	23.72	6.29	20	0	0.00	
21	12975	315	4.85	1,22	3	0	0.00	
22	12712	746	11.74	3.10	8	0	0.00	
23	14420	516	7.16	2.16	5	0	0.00	
30	9014	43	0.95	0.16	2	0	0.00	
12N	11453	1887	32.96	7.61	39	0	0.00	
13N	11453	1660	28.98	6.71	23	0	0.00	
14N	11453	440	7.68	1.66	7	0	0.00	
15N	11453	1698	29.65	7.05	20	3	0.09	0.00-0.20
16N	11453	58	1.01	0.21	3	0	0.00	

Gray Whales

In 1991, highest gray whale density was calculated for block 14 during the latter half of September and block 17 during the first half of October (Table B-3). Lower densities were estimated for blocks 13 and 13N during the latter half of September and for block 14N during the first half of October.

For years 1982-90, relatively high densities were calculated for blocks 13, 14, 14N, 17, 18, 20, and 22 (Table B-3), Lesser indices were calculated for blocks 13N and 23. There were no gray whale density estimates for November in any year.

Cumulative gray whale density estimates were highest in blocks 13, 14, 14N and 22 (Table B-4). Somewhat lower densities were calculated for blocks 12, 13N, 17, 18,20, and 23. As with bowhead density estimates, the overall pattern for abundance is similar to that summarized in the relative abundance table (see Table 21).

Table B-3. Annual semi-monthly estimates of gray whale densities, by survey block, for each year 1982-91.

1991

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)	Confidence Limits
16-30 SEP								
12	11163	742	13.30	3.03	10	0	0.00	
13	13673	1125	16.45	4.60	12	1	0.04	
14	11755	306	5.23	1.31	5	1	0.16	
12N	?1453	311	543	1.27	5	0	0.00	
13N	11453	617	10,78	2.47	9	1	0.08	
14N	11453	439	7.67	1.73	4	0	0.00	
?-15 OCT								
12	11163	1018	18.23	4.31	17	0	0.00	
13	13673	879	12.86	3.66	19	0	0.00	
14	11755	396	6,73	1.55	11	0	0.00	
15	11755	672	11.44	2.78	12	0	0.00	
17	9685	397	8.20	1,79	8	3	0.38	0.00-0.96
?8	12367	1098	17.75	4.57	12	0	0.00	
12N	11453	558	9.74	2.35	8	0	0.00	
?3N	11453	1160	20.26	4.79	15	0	0.00	
14N	11453	1036	18.09	4.24	11	1	0.05	
15N	11453	403	7.03	1.57	7	0	0.00	
16N	11453	667	11.64	2.78	7	0	0.00	

Table B-3. Annual semi-monthly estimates of gray whale densities, by survey block, for each year 1982-91 (Cent'd.).

1989

Block No.	Block Area (km²)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)	Confidence Limits
16-30 SEP								
12	11163	525	9.41	2.39	11	0	0.00	
13	13673	702	10.27	2.85	8	2	0.14	0.00-0.43
15	11755	113	1.92	0.32	3	0	0.00	
18	12367	129	2.08	0.60	2	0	0.00	
12N	11453	980	17.11	4.12	10	0	0.00	
13N	11453	650	11.35	2.75	6	0	0.00	
14N	11453	691	12.07	3.02	6	0	0.00	
15N	11453	774	13.52	3.36	7	0	0.00	
16N	11453	662	11.56	2.74	6	0	0.00	
t-15 OCT								
14	11755	678	11.54	2.77	13	0	0.00	
15	11755	226	3.85	0.94	4	0	0.00	
17	968	562	11.60	2.08	10	0	0.00	
t3N	11453	221	3.86	0,91	2	0	0.00	
14N	11453	688	12.02	3.11	9	7	0.51	0.00-0.90
15N	11453	677	11.82	2.69	7	0	0.00	
16-31 OCT								
?3	?3673	1228	17.96	5.49	17	0	000	
14	11755	146	2.48	0.64	6	0	0.00	
15	11755	409	6.96	1.70	9	0	0.00	
?6	11755	640	10.88	2.67	6	0	0.00	
17	9685	295	6.09	1.30	4	0	0.00	
18	12367	783	12.67	3.38	14	0	0.00	
20	13088	404	6.17	1.79	5	0	0.00	
22	12712	746	11.74	3.10	8	1	0.07	
23	14420	516	7.16	2.16	5	1	0.10	
30	9014	43	0.95	0.16	2	0	0.00	
13N	11453	660	11.52	2.74	7	0	0.00	
15N	11453	632	11.03	2.92	7	0	0.00	

Table B-3. Annual semi-monthly estimates of gray whale densities, by survey block, for each year 1982-91 (Cent'd).

1988

Block No.	Block Area (km²)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)	Confidence Limits
1-15 Ott								
12	11,163	343	6.15	1.29	6	0	0.00	
12N	11,453	556	9.70	2.61	8	0	0.00	
13	13,673	723	10.58	3.59	15	0	0.00	
13N	11,453	765	13.36	2.80	7	0	0.00	
14	11,755	666	11.34	2.78	10	0	0.00	
14N	11,453	483	8.43	2.19	5	0	0.00	
15	11,755	556	9.45	2.09	12	0	0.00	
15N	11,453	685	11,96	2.90	10	0	0.00	
16	11,755	661	11,24	2.55	9	0	0.00	
16N	11,453	776	13,54	3.33	10	0	0.00	
17	9,685	255	5.27	1.19	6	0	0.00	
18	12,367	746	12.07	3.56	8	0	0.00	
19	12,367	163	2.63	0.69	4	0	0.00	

Table B-3. Annual semi-monthly estimates of gray whale densities, by survey block, for each year 1982-91 (Cent'd).

1987

Block No.	Block Area (km²)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km²)	Confidence Limits
16-30 SEP								
12	11163	977	17.50	4.05	16	0	0.00	
13	13673	1424	20.82	5.84	13	5	0.18	0.00-0.34
14	11755	658	11.20	2.5a	7	0	0.00	
15	11755	550	9.36	2.22	7	0	0.00	
16	11755	109	1.85	0.38	1	0	0.00	
?7	9685	418	8.64	1.71	7	0	0.00	
18	12367	664	10.73	2.60	9	0	0.00	
20	13088	114	1.74	0.47	4	0	0.00	
22	12712	302	4.75	1.27	6	1	0.17	
12N	11453	533	9.31	2.25	10	0	0.00	
13N	11453	353	6.17	1.37	9	0	0.00	
16-30 OCT								
12	71163	1083	19.40	4.39	16	0	0.00	
13	13673	569	8.32	2.27	5	1	0.09	
17	9685	443	9.15	1.91	6	0	0.00	
18	12367	110	1.78	0.42	1	0	0.00	
12N	11453	853	14.99	3.45	13	0	0.00	
13N	11453	519	9.06	2.02	6	0	0.00	

Table B-3. Annual semi-monthly estimates of gray whale densities, by survey block, for each year 1982-91. (Cent'd).

1986

Block 540.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales observed	Density (No./100km^2)	Confidence Limits
16-30 SEP								
12	?1163	566	10.14	2.23	8	0	0.00	
13	13673	1205	17.63	4.99	11	6	0.25	0. 00-0.46
14	11755	679	11.55	2.95	6	7	0.52	0.00-0.99
15	11755	472	8.03	1.60	6	0	0.00	
17	9685	453	9.35	1.89	7	0	0.00	
18	?2367	170	2.76	0.70	2	0	0.00	
1-15 OCT								
12	11163	1025	18.37	4.42	15	0	0.00	
13	13673	1118	1635	4.53	15	0	0.00	
14	11755	1150	19.56	458	18	1	0.04	
17	9665	742	15.32	3.15	12	0	0.00	
18	12367	398	6,43	1.55	5	2	0.25	0.00-0.86
12N	11453	8	0.14	003	5	0	0.00	
13N	11453	193	3.36	0.73	9	0	0.00	

Table B-3. Annual semi-monthly estimates of gray whale densities, by survey block, for each year 1982-91. (Cent'd).

1984

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)	Confidence Limits
16-30 SEP								
12	11163	546	9.78	2.45	7	0	0.00	
13	13673	744	10.88	2.93	8	21	1.41	0.00-0.22
14	11755	548	9.32	2.03	5	0	0.00	
17	9665	157	3.25	0.64	4	0	0.00	
1-15 OCT								
12	11163	92?	16.50	3.59	12	0	0.00	
?3	?3673	472	6.90	2.01	5	2	0.21	0.00-0.73
17	9685	409	8.45	1.59	5	0	0.00	
12N	11453	6	0.11	0.03	3	0	0.00	

Table B-3. Annual semi-monthly estimates of gray whale densities, by survey block, for each year 1982-91 (Cent'd),

1982

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)	Confidence Limits
1-15 OCT								
12	11163	1036	18.55	3.88	17	0	0.00	
13	13673	653	9.55	2.47	11	2	0.15	0.00-0.44
14	11755	276	4.70	1.17	8	0	0.00	
17	96$5	752	15.52	2.79	18	2	0.13	0.00-0.36
18	12367	378	6.11	1.29	8	0	0.00	
20	1308a	863	13.19	3.23	9	2	0.12	0.00-0.34
21	12975	237	3.67	0.89	6	0	0.00	

Table B-4. Cumulative (1982-91) semi-monthly estimates of gray whale densities, by survey block.

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)	Confidence Limits
16-30 SEP								
12	11163	5749	103.00	23.70	88	0	0.10	0.00-0.14
13	13673	5617	82.17	23.15	57	35	0.31	0.06-0.28
14	11755	2344	39.88	9.50	29	8	0,17	0.00-0.26
15	11755	1135	19.30	4,34	16	0	0.00	
16	11755	111	1.90	0.40	3	0	0.00	
17	9685	1160	23.76	4.78	22	0	0.09	0.00-023
18	?2367	962	15.56	3.90	13	0	0.00	
20	13088	114	1.74	0.47	4	0	0.00	
22	12712	302	4.75	1.27	6	1	0,17	
12N	11453	1842	32.17	7.72	40	0	0.00	
13N	11453	1624	28.36	6.61	29	1	0.03	
14N	11453	1136	19.84	4.78	15	0	0.00	
15N	11453	777	13.56	3.37	9	0	0.00	
16N	11453	662	11.56	2.74	6	0	0.00	
1-15 OCT								
12	11163	7729	138.48	31.06	113	0	0.00	
13	13673	5522	80.78	22.93	83	4	0.04	0.00-0.07
14	11755	3723	63.34	15.25	75	1	0.01	
15	11755	2238	38.07	8.92	41	0	0.00	
16	11755	662	11.26	2.55	10	0	0.00	
17	9685	4105	84.77	16.45	73	5	0.06	0.00-0.11
18	12367	3293	53.25	13.76	46	2	0.03	0.00-0.08
19	12367	162	2.63	0.69	4	0	0.00	
20	13088	866	13.23	3.24	14	2	0.12	0.00-0.32
21	12975	238	3.67	0.89	6	0	0.00	
22	12712	626	9.84	2.19	8	0	0.00	
12N	11453	1816	31.71	7.91	44	0	0.00	
13N	11453	2562	44.73	10.17	42	0	0.00	
14N	11453	2209	38.58	9.55	28	8	0.18	0.00-0.28
t5N	11453	1873	32.71	7.57	27	0	0.00	
16N	11453	1442	25.18	6.11	17	0	0.00	

Table B-4. Cumulative (1982-91) semi-monthly estimates of gray whale densities, by survey block.

Block No.	Block Area (km^2)	Transect Distance (km)	Percent Area Surveyed	Transects Time (h)	No. Transects Flown	No. Whales Observed	Density (No./100km^2)	Confidence Limits
16-31 OCT								
12	?1163	5445	97.55	22.20	73	0	0.00	
13	13673	5455	79.79	22.75	74	1	0.01	
14	11755	1513	25.73	5.95	31	0	0.00	
15	11755	749	12.74	3.07	19	0	0.00	
16	11755	1302	22.15	5.30	12	0	0.00	
17	9685	1471	30.37	6.21	24	0	0.00	
18	?2387	2186	35.03	8.89	33	0	0.00	
19	12367	335	5.42	1.33	7	0	0.00	
20	13088	1552	23.72	6.29	20	0	0.00	
21	12875	315	4.85	1,22	3	0	0.00	
22	12712	746	11.74	3.10	8	1	0.07	
23	14420	516	7.16	2.16	5	1	0.10	
30	8014	43	0.95	0.16	2	0	0.00	
12N	11453	1887	32.96	7.61	39	0	0.00	
13N	11453	1660	28.98	6.71	23	0	0.00	
14N	11453	440	7.68	1,66	7	0	0.00	
15N	11453	1698	29.65	7,05	20	0	0.00	
16N	t 1453	58	1.01	0.21	3	0	0.00	

DISCUSSION

Even the highest estimates provided here suggest that density of bowhead and gray whales in the study area is extremely low. This is likely due, at least in part, to the procedures involved in density estimation. Two elements inherent in a study of cetaceans that cause an individual to be missed during transect surveys are visibility bias and submergence. Visibility bias includes factors such as surface conditions and observer capability/fatigue that cause a whale at the surface to be missed during a survey. Although the sighting distance histogram (Fig. B-2} indicated that the probability of sighting surfaced bowheads within one kilometer of the aircraft was relatively high, some whales were undoubtedly missed. Submerged whales represent a source of known but unmeasurable error in density estimates. Although dive profiles obtained for bowheads summering in the Canadian Beaufort Sea and while feeding in the Alaskan Beaufort Sea (Dorsey et al. 1989; Ljungblad et al. 1987) have been used to calculate estimates of bowhead whale numbers (Moore and Clarke 1991), broad variability in dive profiles argues against applying them as correction factors to specific density estimates.

Density estimates have long been used by wildlife biologists, even though satisfying the assumptions underlying the statistic is often impossible (Eberhardt et al. 1979). A key assumption which is seldom upheld is that all animals within the transect strip are seen (i.e., visibility bias). Graham and Bell (1988) investigated observer bias during aerial surveys for equines and reported that observers overlooked 12.8 to 43.8% of the groups of visible animals in their field of view. These results are generally comparable to a short-term double-count trial conducted by Davis et al. (1982) during aerial surveys for bowhead whales in the Canadian Beaufort Sea, which indicated that surfaced bowheads were missed by observers 30 to 35% of the time. More recently, Marsh and Sinclair (1989) reported using tandem observer teams to correct for visibility bias in strip transect aerial surveys for dugongs (Dugong dugon). Double-count survey techniques required to correct density estimates for visibility bias are labor intensive, both in the field and during analysis, and have generally been outside the scope of this project.

Four additional assumptions peculiar to estimating cetacean density and potential biases that result when they are not met include:

1) Whale behavior does not change during the period for which an estimate is calculated. This assumption is critical, but difficult to satisfy because whales' behaviors do change during the study period; net bias may **be** upward or downward largely depending on surface time associated with the behaviors exhibited (Dorsey et al. 1989).

2) Observers are equally effective on both sides of the aircraft and in all portions of the study area. This assumption results from each observer's sightings being equally weighted by formulas used in calculating density estimates. Deviation from this assumption will cause a negative or downward bias on the final estimates. Visibility bias associated with observer fatigue, eyesight and experience can lead to significant underestimation of population abundance from aerial survey data (Samuel et al. 1987; Pollock and Kendall 1987).

3) Group size does not affect detection of whales. A violation of this assumption causes a negative bias since larger groups have a greater likelihood of being sighted (Graham and Bell 1988).

4) Whales do not evade the aircraft. This assumption is probably met because the speed of the aircraft is much greater than that of the whale.

The problems in meeting the assumptions outlined above are not unique to the task of estimating bowhead or gray whale density. The Scientific Committee of the IWC has struggled with various models to estimate density and population number for a variety of cetacean species over the years (IWC 1989; Hi by and Hammond 1989). Further, Eberhardt and Simmons (1987) note that in practice most wildlife managers rely on abundance indices to assess populations, and suggest a method of 'double sampling' as a means of calibrating absolute abundance estimates. The double sampling method requires that random sampling be observed in the derivation of both indices, however, so although estimates of endangered whale density can be compared to WPUE (Tables 16 and 21), they can not be correlated statistically.

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APPENDIX C

SUMMARY OF BOWHEAD AND GRAY WHALE SIGHTINGS NEAR OFFSHORE EXPLORATORY DRILLING SITES IN THE CHUKCHI SEA STUDY AREA, 1989-91

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INTRODUCTION

The primary objectives of the three year (1989-91) aerial survey study described herein were to determine the distribution, relative abundance and movements of bowhead and gray whales in relation to proposed or existing Federal lease sale areas in the Alaskan Chukchi and western Beaufort seas. This required conducting broad-scale aerial surveys over a very large study area that encompassed the Hope Basin Planning Area, the Chukchi Sea Planning Area and the westernmost portion of the Beaufort Sea Planning Area (see Fig. 1). A secondary objective was to make detailed observations of bowhead and gray whale behaviors, if whales were seen near (within ca. 20 km) an active exploratory drilling site during the course of broad-scale surveys. These observations were to include measures of respiratory rates and descriptions of swimming patterns and any unusual behaviors, similar to published accounts of whale behaviors near active geophysical survey vessels and offshore exploratory drilling activities in the Beaufort Sea (eg., Richardson et al. 1986, 1990; Ljungblad et al. 1988). Behavioral observations of this type were not made because bowhead and gray whales were never seen near an active exploratory drilling site (Table C-1), This is likely due to the intermittent nature of survey effort near drilling sites resulting from: a) the very large study area to be surveyed; and b) the fact that site-specific surveys were conducted by other researchers in association with exploratory drilling at each site.

Survey effort, whale position and polar coordinates referenced to the drilling site, and observed swimming direction for bowhead and gray whales, are summarized in this appendix to provide an account of observations made during the course of this study in relation to active offshore exploratory drilling activities. These records are augmented by sightings made during site-specific surveys conducted by other researchers. The reader is encouraged to consult the reports describing site-specific surveys for additional information regarding underwater noise measurements and marine mammal occurrence near offshore exploratory drilling operations in the Chukchi Sea study area. Further, a comprehensive summary of studies focused on the effects of noise associated with offshore exploratory drilling operations on marine mammals is presented in Richardson et al. (1991).

Table C-1. Exploratory drilling sites, periods of active operation, and the closest bowhead-to-site distance in the study area, 1989-91. Please Note: bowhead whale sightings listed are for this study only (see text). * = On-location date, active drilling commenced on 1 November; all other dates are drilling spud-and-end dates. N/A = Not Applicable to survey period.

SITE NAME	LOCATION	PERIOD	CLOSEST BOWHEAD WHALE Date	Distance
1989:				
Klondike	70°43'N, 165°15'W	9 Jul-15 Sep	N/A	N/A
Burger	71°15'N, 163°12'W	22 Sep-13 Ott	10 Ott	122 km
Popcorn	71°51'N, 165°48'W	14 Ott-l 9 Ott	16 Ott	77 km
1990:				
Popcorn	71051'N, 165°48'W	12 Jul-29 Jut	N/A	N/A
		22 Aug-22 Sep	N/A	N/A
Burger	71°15'N, 163°12'W	29 Jul-22 Aug	N/A	N/A
Crackerjack	71025'N, 165°32'W	22 Sep-11 Ott	11 Ott	295 km
1991:				
Crackerjack	71°25'N, 165°32'W	19 Jul-31Aug	N/A	N/A
Diamond	7102O'N, 16104I'W	7 Sep-5 Ott	29 Sep	90 km
Cabot	71°19'N, 155°13'W	28 Aug*-present	6 Ott	18 km

SIGHTING SUMMARIES

Survey Effort and Bowhead and Gray Whale Sightings in Relation to Active Exploratory Drilling Sites

Active exploratory drilling operations were conducted at three (3) sites during the summer' and early fall of each year 1989-91. However, drilling activities continued into this project's survey period at only two (2) sites in 1989 and at one (1) site each year 1990-91. Bowhead and gray whale sightings made while active drilling was ongoing are summarized below for each site, by year, These summaries are accompanied by a period-specific survey effort map and a table listing whale sighting locations, observed swimming direction, and polar coordinates referenced to the drilling site.

1989

Exploratory drilling was conducted at the 'Burger' site from 22 September-13 October and at the 'Popcorn' site from 14-19 October. From 22 September-11 October (Flights 3-15), there were 13 sightings for a total of 47 bowhead whales, and 15 sightings for a total of 31 gray whales (Fig. C-l). The closest observed bowhead was 122 km from the 'Burger' site, while the closest observed gray whale was 70 km from the site. Most of the bowheads were part of a feeding aggregation seen northeast of Point Barrow on 5 October 1989 (Moore and Clarke 1990). From 14-19 October (Flights 16-19), there were 18 sightings for a total of 30 bowhead whales, and 6 sightings for a total of 13 gray whales (Fig. C-2). The closest observed bowhead was 77 km from the 'Popcorn' site and the closest observed gray whale was 246 km from the site.

1990

Exploratory drilling was conducted at the 'Crackerjack' site from 22 September-1 1 October. Only three surveys {Flights 1-3) were conducted during this period due to the lack of a dedicated survey aircraft (Moore and Clarke 1991). There were 5 sightings for a total of 7 bowhead whales and 1 sighting of 1 gray whale from 3-11 October (Fig. C-3). The closest observed bowhead was 295 km from the 'Crackerjack' site, while the gray whale was 303 km from the site.

Table C-2. Position and polar coordinates for bowhead and gray whale sightings during the period of active drilling at the 'Burger' site, 22 September-13 October 1989.

Origin: 'Burger' site (71" 15'N, 163012'W)

Bowhead Whales

Date:	Flight#:	Long:	Lat:	Total#:	Angle:	Radius:	Swim Dir:
9/22/1989	3	163140	72476	1	90 degs	172 km	204 degs
9/30/1989	9	154132	71052	3	357 degs	323 km	---
9/30/1989	9	156490	71310	1	7 degs	228 km	294 degs
10/ 5/1989	12	155100	71160	3	0 degs	287 km	---
10/ 5/1989	12	155150	71180	5	1 degs	284 km	---
10/ 5/1989	12	155200	71200	2	2 degs	281 km	---
10/ 5/1989	12	155350	71220	6	3 degs	272 km	---
10/ 5/1989	12	155450	71230	5	3 degs	266 km	---
10/ 5/1989	12	155550	71240	7	4 degs	260km	---
10/ 5/1989	12	156050	71250	4	4 degs	254 km	---
10/ 5/1989	12	156150	71260	6	5 degs	248 km	---
10/ 5/1989	12	156200	71270	3	5 degs	245 km	---
10/10/1989	14	162096	72181	1	73 degs	122 km	324 degs

Gray Whales

Date:	Flight#:	Long:	Lat:	Total#:	Angle:	Radius :	Swim Dir:
9/22/1989	3	161022	71466	3	38 degs	96 km	---
9/22/1989	3	160599	71459	3	36 degs	96 km	---
9/23/1989	4	161219	71430	1	39 degs	83km	---
9/23/1989	4	161497	71421	1	46 degs	70 km	---
9/27/1989	6	159273	70523	1	343 degs	141 km	314 degs
9/27/1989	6	158597	70576	1	348 degs	155 km	---
9/27/1989	6	158535	70571	4	348 degs	159 km	264 degs
9/27/1989	6	158464	70574	1	348 degs	163 km	234 degs
9/27/1989	6	158379	71014	2	351 degs	166 km	---
10/ 9/1989	13	161041	71474	1	39 degs	96 km	---
10/ 9/1989	13	161030	71448	2	36 degs	94 km	---
10/ 9/1989	13	161046	71448	1	36 degs	93km	---
10/ 9/1989	13	160569	71440	3	34 degs	96 km	---
10/10/1989	14	162176	72192	6	75 degs	123 km	---
10/10/1989	14	162084	72153	1	72 degs	118 km	---

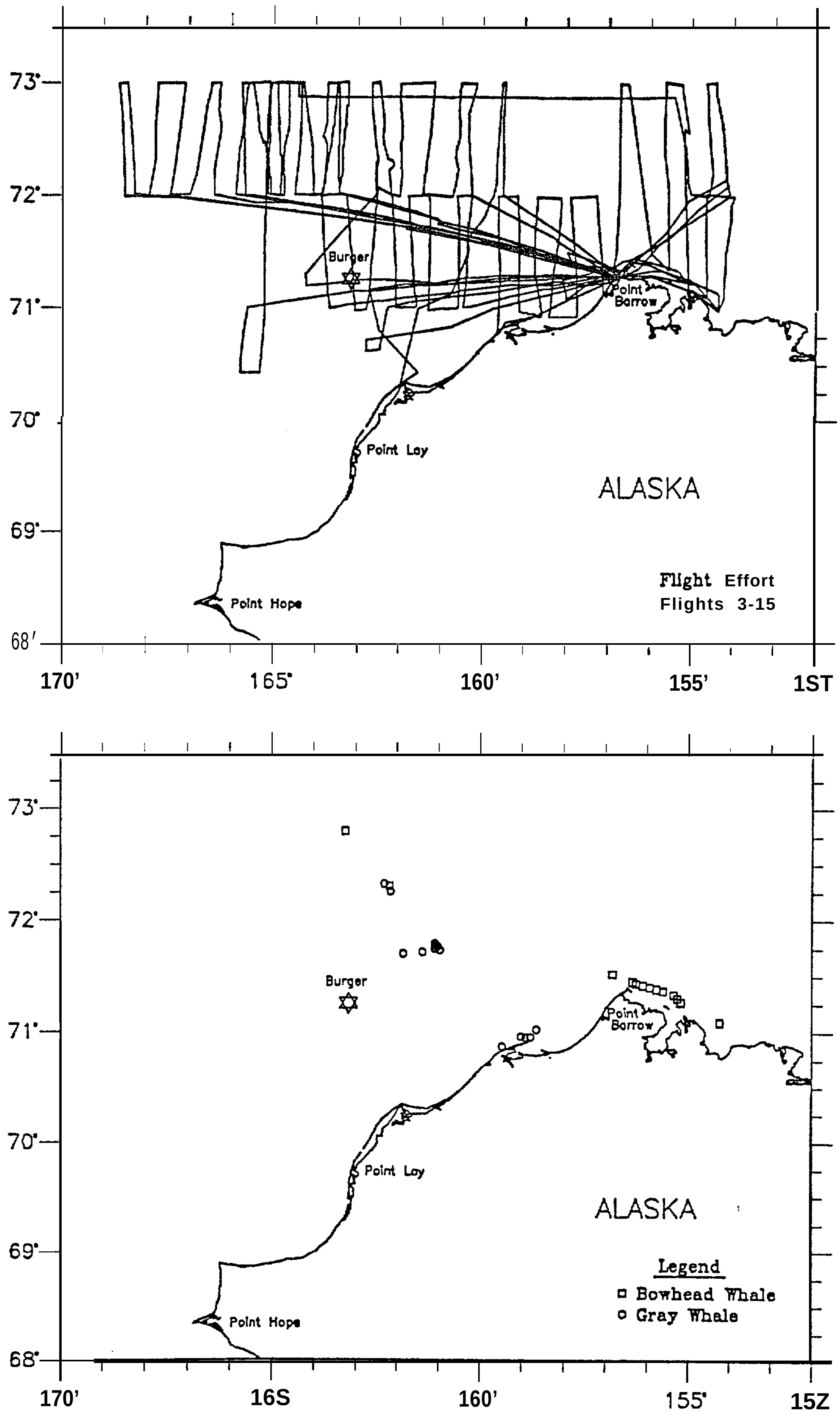


Figure C-1. Survey effort and bowhead and gray whale sightings during the period of active drilling at the 'Burger' site, 22 September-13 October 1989.

Table C-3. Position and polar coordinates for bowhead and gray whale sightings during the period of active drilling at the 'Popcorn' site, 14-19 October 1989.

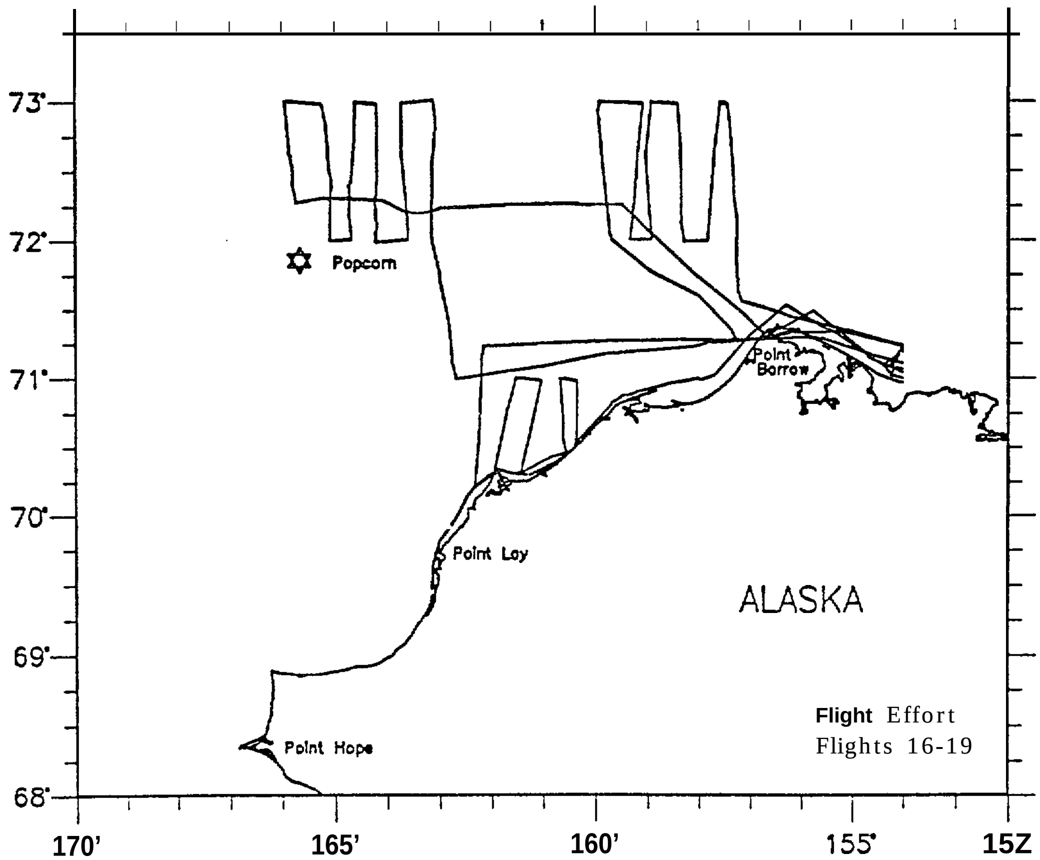
Origin: 'Popcorn' site (71 "51 'N, 165 °48'W)

Bowhead Whales

Date:	Flight# :	Long:	Lat:	Total#:	Angle:	Radius:	Swim Dir:
10/14/1989	16	154405	71092	1	349 degs	400 km	---
10/14/1989	16	154450	71120	2	349 degs	396 km	284 degs
10/15/1989	17	154137	71067	3	349 degs	417 km	---
10/15/1989	17	154108	71023	1	348 degs	421 km	314 degs
10/15/1989	1 7	154174	71030	1	348 degs	417 km	324 degs
10/15/1989	17	154196	71045	1	348 degs	414 km	254 degs
10/15/1989	17	154212	71064	3	348 degs	413 km	284 degs
10/15/1989	1 7	154123	71048	5	348 degs	419 km	---
10/15/1989	17	154136	71016	1	347 degs	420 km	94 degs
10/15/1989	1 7	154195	71050	3	348 degs	414 km	164 degs
10/15/1989	17	154242	71061	1	348 degs	411 km	264 degs
10/15/1989	17	155198	71202	1	351 degs	372 km	264 degs
10/15/1989	17	155310	71222	2	352 degs	365 km	354 degs
10/16/1989	18	165491	72325	1	90 degs	77 km	264 degs
10/19/1989	19	155321	71174	1	350 degs	366 km	69 degs
10/19/1989	19	156098	71272	1	353 degs	340 km	84 degs
10/19/1989	19	156118	71274	1	353 degs	339 km	284 degs
10/19/1989	19	156189	71284	1	353 degs	334 km	84 degs

Gray Whales

Date:	Flight#:	Long:	Lat:	Total#:	Angle:	Radius :	Swim Dir:
10/15/1989	17	157599	71005	1	341 degs	292 km	184 degs
10/15/1989	17	159209	70531	5	335 degs	253 km	274 degs
10/15/1989	17	159280	70527	1	334 degs	250 km	94 degs
10/15/1989	17	159367	70504	4	333 degs	247 km	224 degs
10/15/1989	17	159398	70500	1	333 degs	246 km	204 degs
10/15/1989	17	159415	70488	1	332 degs	246 km	---



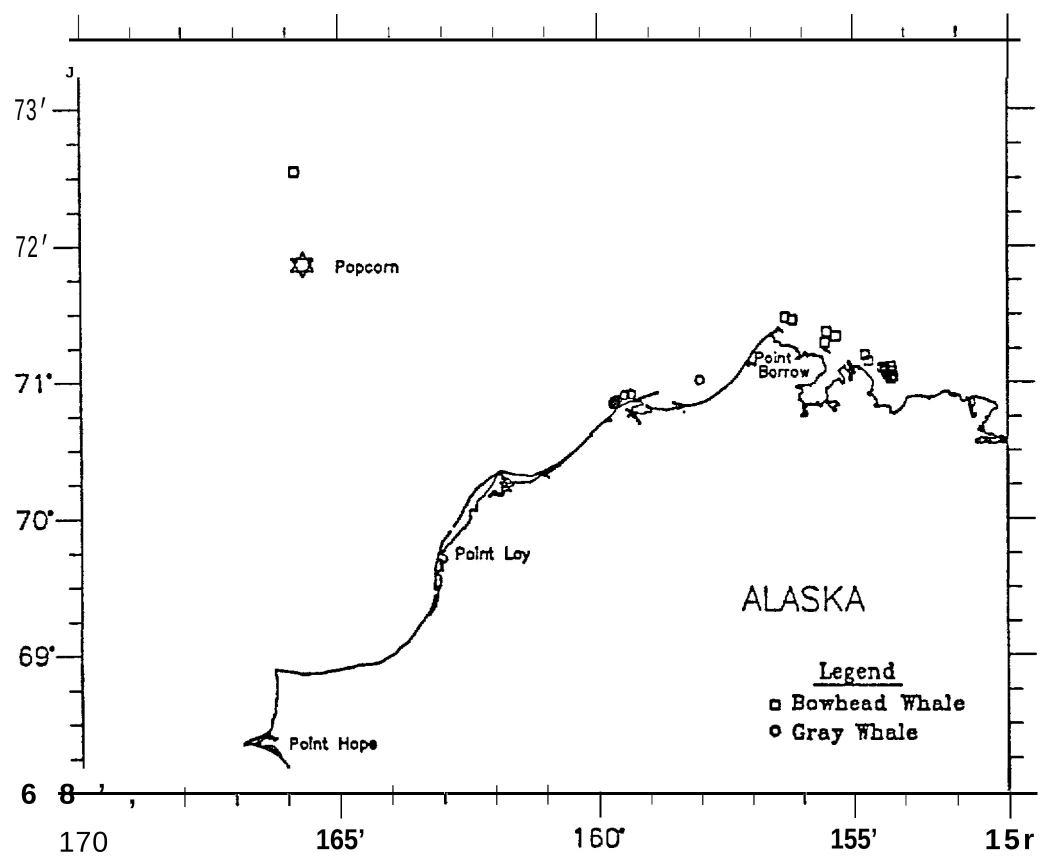


Figure C-2. Survey effort and bowhead and gray whale sightings during the period of active drilling at the 'Popcorn' site, 14-19 October 1989.

Table C-4. Position and polar coordinates for bowhead and gray whale sightings during the period of active drilling at the 'Crackerjack' site, 22 September -11 October 1990.

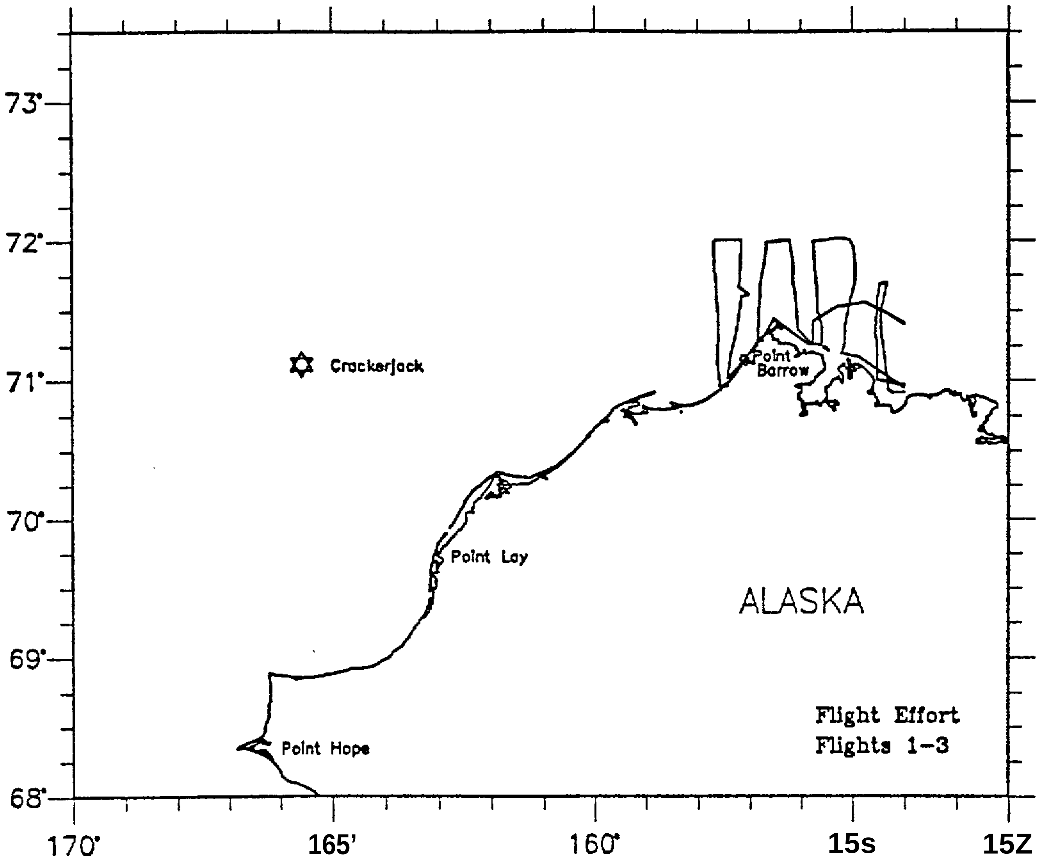
Origin: 'Crackerjack' site (71 * 25'N, 165 °32'W)

Bowhead Whales

Date:	Flight#:	Long:	Lat:	Total#:	Angle:	Radius:	Swim Dir:
10/ 9/1990	2	154324	71181	1	358 degs	391 km	274 degs
10/ 9/1990	2	154338	71202	1	359 degs	389 km	234 degs
10/11/1990	3	157119	71404	1	6 degs	295 km	294 degs
10/11/1990	3	156470	71393	2	5 degs	309 km	294 degs
10/11/1990	3	156066	71377	2	4 degs	333 km	---

Gray Whales

Date:	Flight#:	Long:	Lat:	Total#:	Angle:	Radius :	Swim Dir:
10/11/1990	3	157055	71091	1	354 degs	303 km	304 degs



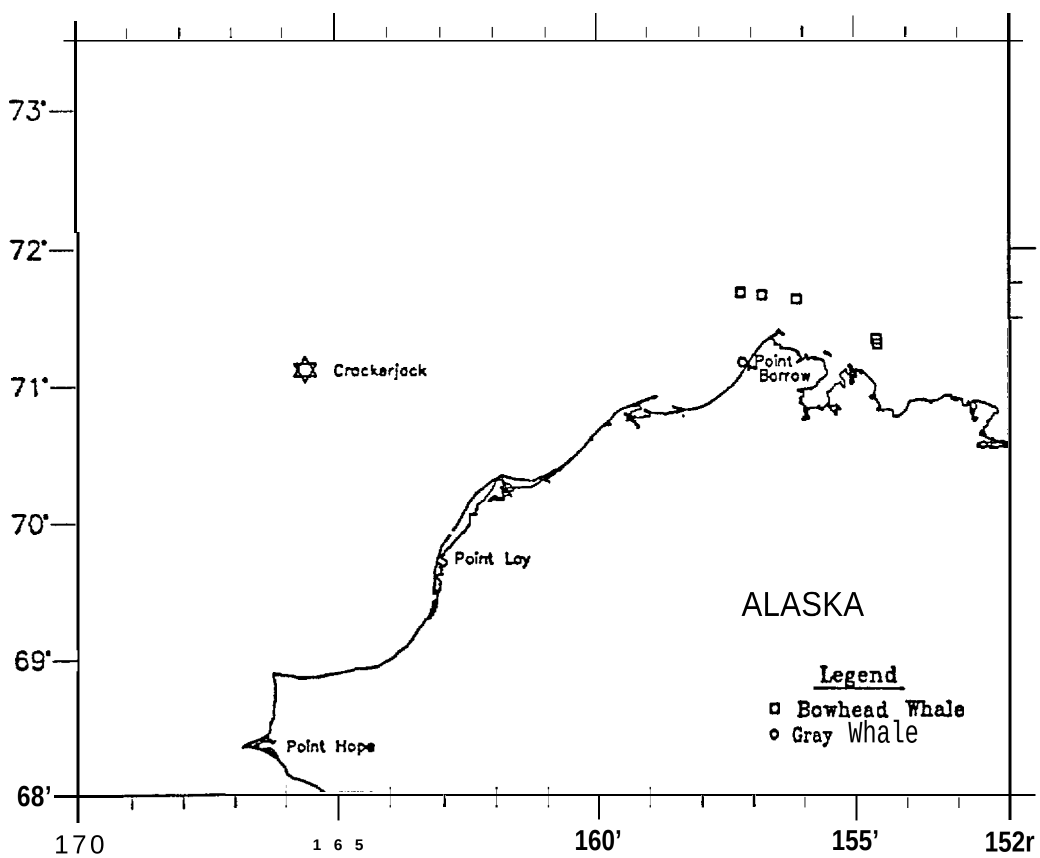


Figure C-3. Survey effort and bowhead and gray whale sightings during the period of active drilling at the 'Crackerjack' site, 22 September-11 October 1990.

1991

Exploratory drilling was conducted at the 'Diamond' site from 7 September-5 October. Although surveys began on 20 September, the first bowheads were not seen until 29 September. From 20 September-5 October (Flights 1-12), there were 6 sightings for a total of 8 bowhead whales and 18 sightings for a total of 23 gray whales (Fig. C-4). The closest bowhead was 90 km from 'Diamond' site, while the closest gray whale was 27 km from the site.

A bottom-founded drilling structure was towed to the 'Cabot' site on 28 August and remained on warm standby, but did not commence exploratory drilling until 1 November, after the survey period. There were 27 sightings for a total of 32 bowhead whales and 20 sightings for a total of 26 gray whales during the survey season. The closest observed bowhead was 18 km from the 'Cabot' site, while the closest observed gray whale was 58 km away (please see Figs. 5, 7 and 11 for seasonal survey effort and sighting summaries).

Table C-5. Position and polar coordinates for bowhead and gray whale sightings during the period of active drilling at the 'Diamond' site, 7 September -5 October 1991.

Origin: 'Diamond' site (71 °20'N, 161 °41'W)

Bowhead Whales

Date:	F1.ight#:	Long:	Lat:	Total#:	Angle:	Radius:	Swim Dir:
9/29/1991	7	158232	71352	1	14 degs	120 km	264 degs
9/29/1991	7	159213	71396	1	24 degs	90 km	264 degs
9/29/1991	7	159225	71523	1	36 degs	101 km	264 degs
10/ 3/1991	10	154215	71246	1	2 degs	260 km	54 degs
10/ 3/1991	10	155492	72032	2	21 degs	220 km	84 degs
10/ 3/1991	10	156129	71388	2	10 degs	196 km	284 degs

Gray Whales

Date:	Flight#:	Long:	Lat:	Total():	Angle:	Radius :	Swim Dir:
9/22/1991	3	157487	72059	1	32 degs	160 km	264 degs
9/24/1991	4	160450	71338	1	38 degs	42 km	24 degs
9/24/1991	4	160386	71221	1	6 degs	37 km	24 degs
9/24/1991	4	161260	71340	1	71 degs	27 km	254 degs
9/27/1991	5	156500	71190	1	359 degs	173 km	354 degs
9/29/1991	7	157537	71066	1	350 degs	138 km	---
9/29/1991	7	158218	71103	1	351 degs	120 km	---
9/29/1991	7	158381	71036	1	344 degs	113 km	154 degs
10/ 1/1991	8	162324	70260	1	253 degs	105 km	244 degs
10/ 1/1991	8	160568	70316	1	287 degs	94 km	294 degs
10/ 1/1991	8	160561	70308	1	287 degs	95 km	294 degs
10/ 1/1991	8	160030	70448	2	312 degs	88 km	284 degs
10/ 1/1991	8	159578	70442	1	313 degs	91 km	284 degs
10/ 1/1991	8	159553	70454	1	315 degs	90 lull	284 degs
10/ 1/1991	8	160030	70532	1	320 degs	77 km	174 degs
10/ 1/1991	8	160052	70537	3	320 degs	75 km	---
10/ 1/1991	8	158200	71094	3	351 degs	121 km	254 degs
10/ 2/1991	9	162282	72155	1	105 degs	106 km	84 degs

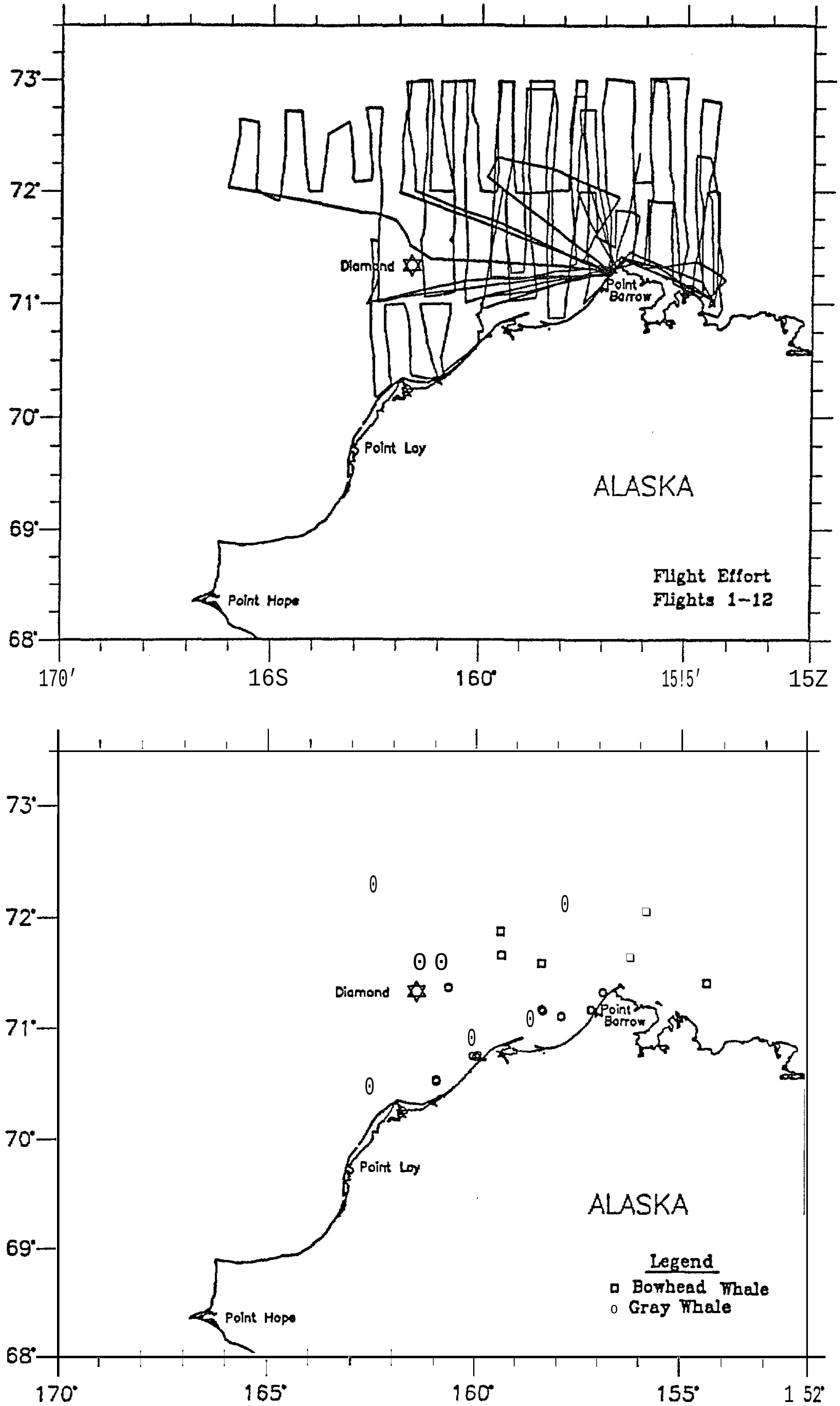


Figure C-4. Survey effort and bowhead and gray whale sightings during the period of active drilling at the 'Diamond' site, 7 September-5 October 1991,

Bowhead and Gray Whale Sightings during Site-Specific Surveys by Other Researchers

Site-specific surveys were conducted by Ebasco Environmental each year 1989-91 in association with exploratory drilling operations in the Chukchi Sea. Marine mammal sightings were collected during aerial surveys conducted along systematic transect lines centered on the drilling sites, and by an observer onboard an icebreaking vessel associated with the sites. In 1989 and 1990, the study focus was to determine the response of walruses and polar bears to drilling operations (Brueggeman [cd.] 1990, 1991), while in 1991 the focus was the response of seals and whales to icebreaking and drilling operations (Brueggeman [cd.] 1992).

Site-specific surveys were conducted by COPAC in 1991 in association with the 'Cabot' site in the western Beaufort Sea. Marine mammal sightings were collected during aerial surveys conducted along systematic transect lines centered on the platform, and by an observer onboard the platform.

1989

Bowhead whales were not seen during aerial surveys that were flown intermittently by Ebasco biologists from 25 June -15 September. Twenty-six sightings for a total of 34 gray whales were recorded from 25 June through 2 July (Brueggeman [cd.] 1990), prior to the onset of drilling activities at the 'Klondike' site on 9 July (see Table C-1). One gray whale was seen on 15 September, the last day of drilling at the 'Klondike' site, at 72"17'N, 162°27'W.

1990

Bowhead whales were not seen during aerial surveys that were flown intermittently by Ebasco biologists from 29 June-5 October. Six sightings for a total of seven gray whales were recorded on 9 July (Brueggeman [cd.] 1991), prior to the onset of drilling activities at the 'Popcorn' site on 12 July (see Table C-1). One gray whale was seen by a shipboard observer on 25 July, during drilling activities at the 'Popcorn' site,

1991

Forty-two sightings for a total of 51 bowhead whales and 56 sightings for a total of 120 gray whales were recorded from 29 June through 5 November by biologists conducting surveys near offshore exploration sites in the Chukchi Sea study area (Figs. 5 and 6). Surveys within about 40 km of 'Crackerjack' and 'Diamond' drilling sites in the Chukchi Sea were conducted by Ebasco Environmental (Brueggeman [cd.] 1992); surveys near the 'Cabot' site in the western Beaufort Sea were conducted by COPAC (Gallagher et al. 1992).

Ebasco Environmental

Ebasco conducted aerial surveys, primarily for walrus, in the Chukchi Sea intermittently from 29 June through 8 October 1991. Twelve sightings of 15 bowhead whales were recorded (Fig. C-5). Three whales were seen in late August and twelve in early October, nine of which were recorded on 7 October. There were 39 sightings of 48 gray whales from 16 August through 8 October (Fig. C-5). Thirty seven whales were seen in late August, nine in early September and two in mid-September.

COPAC

COPAC conducted aerial surveys, primarily for bowhead whales, from 21 August through 14 October. Thirty sightings of 36 bowhead whales were recorded (Fig. C-6). Three whales were seen in late September; the other thirty-three, including three calves, were seen in the first half of October. Seventy gray whales were seen {Fig. C-6); 16 were recorded in mid-August, 51 in late August, and three in mid-September.

Additionally, an ARCO pilot with extensive marine mammal survey experience reported a sighting of two gray whales near Barrow on 5 November on a routine flight between Prudhoe Bay and Wainwright. This sighting is included in Figure C-6.

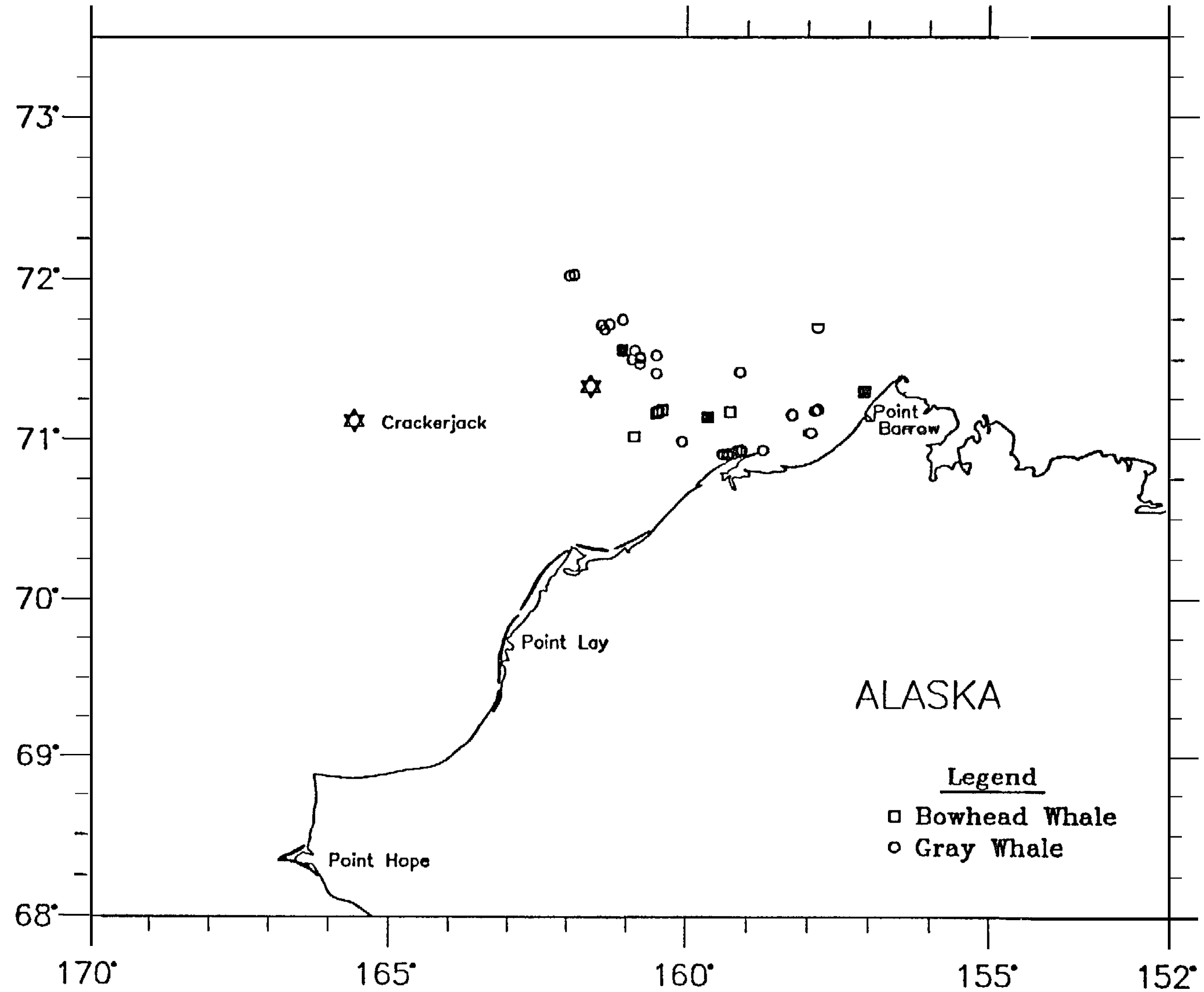


Figure C-5. Distribution of 12 sightings for a total of 15 bowhead whales and 39 sightings for a total of 48 gray whales by Ebasco biologists conducting surveys near offshore exploration sites in the Chukchi Sea study area, 29 June-8 October, 1991. ■ = bowhead whales seen 24-26 August.

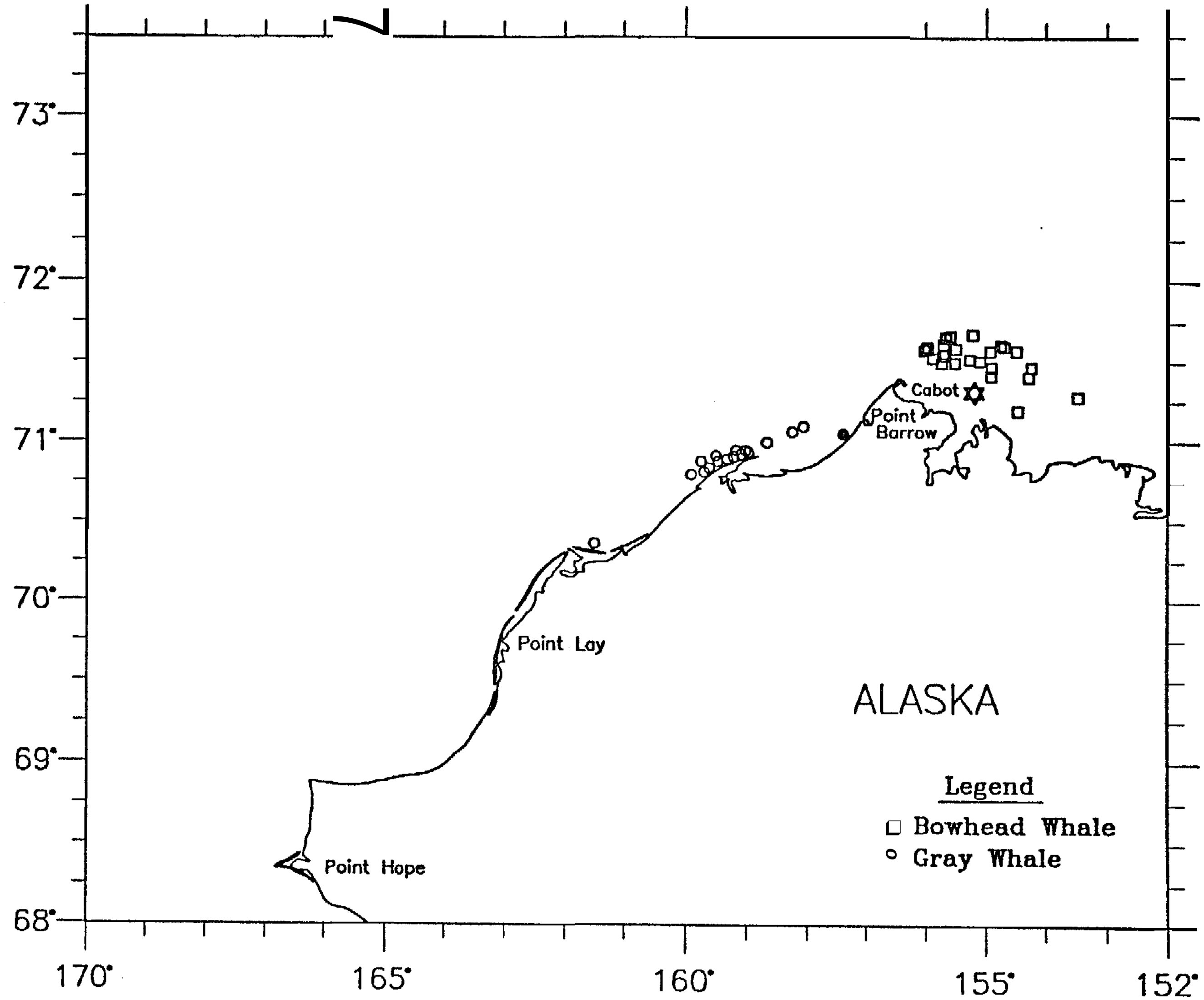


Figure C-6. Distribution of 30 sightings for a total of 36 bowhead whales and 17 sightings for a total of 72 gray whales by COPAC biologists (1 sighting of 2 whales by ARCO pilot) conducting aerial surveys near an inactive offshore exploration site in the Chukchi Sea study area, 21 August -5 November 1991. ● = gray whales seen 5 November (COPAC/ARCO).

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